(Technical Review Draft, April 2002)

GILA TROUT (*Oncorhynchus gilae*)

(Third Revision)

RECOVERY PLAN

(Original Approved: January 12, 1979)
(First Revision Approved: January 3, 1984)
(Second Revision Approved: December 8, 1993)

Prepared by John Pittenger (Purchase Order 201819M251)

for

Region 2
U.S. Fish and Wildlife Service
Albuquerque, New Mexico

Approved: XXX
Regional Director, U.S. Fish and Wildlife Service

Date: ______________________

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Literature citation of this document should read as follows:

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EXECUTIVE SUMMARY

Current Species Status Gila trout, native to streams of the Mogollon Plateau of New Mexico and Arizona, is listed as endangered throughout its range. In 1975, the known distribution of the species consisted of only five relict populations restricted to headwater stream habitats in the upper Gila River drainage in New Mexico (Main Diamond Creek, South Diamond Creek, McKenna Creek, Spruce Creek and Iron Creek). At the time of listing, no detailed genetic investigations of the few extant populations had been undertaken. Thus, each of the five known occurrences was considered a pure population and essential to recovery. A sixth relict population in Whiskey Creek was discovered in 1992. In 1996 and 1997, it was discovered that the McKenna Creek and Iron Creek populations were hybridized with rainbow trout. Replication of these two hybrid populations is not a component of recovery of Gila trout because Gila *x* rainbow hybrid trout are not recognized as a species or subspecies pursuant to the Endangered Species Act and published listing rules for the species.

Currently, there are 14 populations of Gila trout in the wild. Additionally, the Mora National Fish Health and Technology Center maintains a captive population of Gila trout that represents the Main Diamond lineage. The downlisting criteria described in the 1993 recovery plan revision have been achieved. All of the relict populations are self-sustaining in the wild. All pure populations have been replicated in a sufficient number of drainages to prevent extirpation of any lineage from a natural or human-caused event. The Main Diamond Creek population was restored to its original habitat following its loss in the wild from the 1989 Divide Fire. Replicates of the Main Diamond Creek population persist in McKnight Creek, Sheep Corral Canyon, lower Little Creek, upper White Creek, and Black Canyon. Similarly, the South Diamond Creek population was restored to its original habitat following its loss in the wild from the 1995 Bonner Fire. The South Diamond Creek population is replicated in the Mogollon Creek drainage, which includes a portion of the main stem of Mogollon Creek, Trail Canyon, Woodrow Canyon, and South Fork Mogollon Creek. The Whiskey Creek population is replicated in upper Little Creek and the Spruce Creek population is replicated in Big Dry Creek, Dude Creek, and Raspberry Creek. The total population size of Gila trout in the wild was estimated to be approximately 37,000 in 1998.

Habitat Requirements and Limiting Factors Gila trout is found in moderate- to high-gradient perennial mountain streams above 1,660 m (5,400 ft) elevation. Streams typically flow through narrow, steep-sided canyons and valleys. The species requires water temperatures below 25ºC (77ºF), clean gravel substrates for spawning, continuous stream flow of sufficient quantity to maintain adequate water depth and temperature, and pool habitat that provides refuge during low flow conditions and periods of thermal extremes. Abundant invertebrate prey, cover, and water free from contaminants are also required. Cover typically consists of undercut banks, large woody debris, deep pools, exposed root masses of trees at waters edge, and overhanging vegetation.

Recovery Objective and Criteria The objective of this recovery plan is to downlist and then delist the Gila trout. Downlisting of Gila trout will be considered when: 1) all known, non-hybridized, indigenous lineages are replicated in the wild; and 2) Gila trout are established in a sufficient number of drainages such that no natural or human-caused event may eliminate a non-hybridized, indigenous lineage. Gila trout will be considered for delisting when: 1) at least 20 populations in the Gila River Recovery Unit are established in at least 150 km (93 mi) of stream; 2) at least 15 populations in the San Francisco River

Recovery Unit are established in at least 80 km (50 mi) of stream; and 3) at least four San Francisco-Gila River mixed lineage populations are established in at least 40 km (25 mi) of stream.

Actions Needed Actions needed to achieve the objective of this plan include: 1) establishing additional populations of Gila trout, including restoring the species in entire watersheds and recombining lineages; 2) protecting populations and habitat; 3) continuing to obtain information needed to address important conservation issues; and, 4) continuing to provide information and conduct coordination regarding recovery of the species.

Implementation Participants The U.S. Fish and Wildlife Service, U.S. Forest Service, New Mexico Department of Game and Fish, and Arizona Game and Fish Department are participants in implementing recovery actions for Gila trout.

Total Estimated Cost of Recovery

Year	Need 1: Establish Populations	Need 2: Protect Populations and Habitat	Need 3: Investigate Conservation Issues	Need 4: Communication and Coordination	Total
1	$150,000	$50,000	$2,000	$5,000	$207,000
2	$150,000	$50,000	$2,000	$5,000	$207,000
3	$150,000	$50,000	$2,000	$5,000	$207,000
4	$150,000	$50,000	$2,000	$5,000	$207,000
5	$150,000	$50,000	$2,000	$5,000	$207,000
6	$70,000	$50,000	$0	$5,000	$125,000
7	$70,000	$50,000	$0	$5,000	$125,000
8	$70,000	$50,000	$0	$5,000	$125,000
9	$70,000	$50,000	$0	$5,000	$125,000
10	$70,000	$50,000	$0	$5,000	$125,000
Total	$1,060,000	$500,000	$10,000	$50,000	$1,620,000

Date of Recovery Delisting of Gila trout is anticipated to occur within 10 years following reclassification to threatened.

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INTRODUCTION

Gila trout (*Oncorhynchus gilae*) is endemic to mountain streams in the Gila, San Francisco, Agua Fria, and Verde river drainages in New Mexico and Arizona (Miller, 1950; Minckley, 1973:61-62; Behnke, 1992:212-214). Although the species was known in the upper Gila River basin since at least 1885, it was not described until 1950, by which time its distribution had been dramatically reduced (Miller, 1950). Gila trout was originally recognized as endangered under the Federal Endangered Species Preservation Act of 1966 (U.S. Fish and Wildlife Service, 1967). Federal-designated status of the fish as endangered was continued under the Endangered Species Act of 1973 (U.S. Fish and Wildlife Service, 1975). Gila trout was listed as endangered by the New Mexico Department of Game and Fish in 1975 under the Wildlife Conservation Act and was downlisted to threatened in 1988. Gila trout are considered a Species of Concern by the Arizona Game and Fish Department.

DESCRIPTION

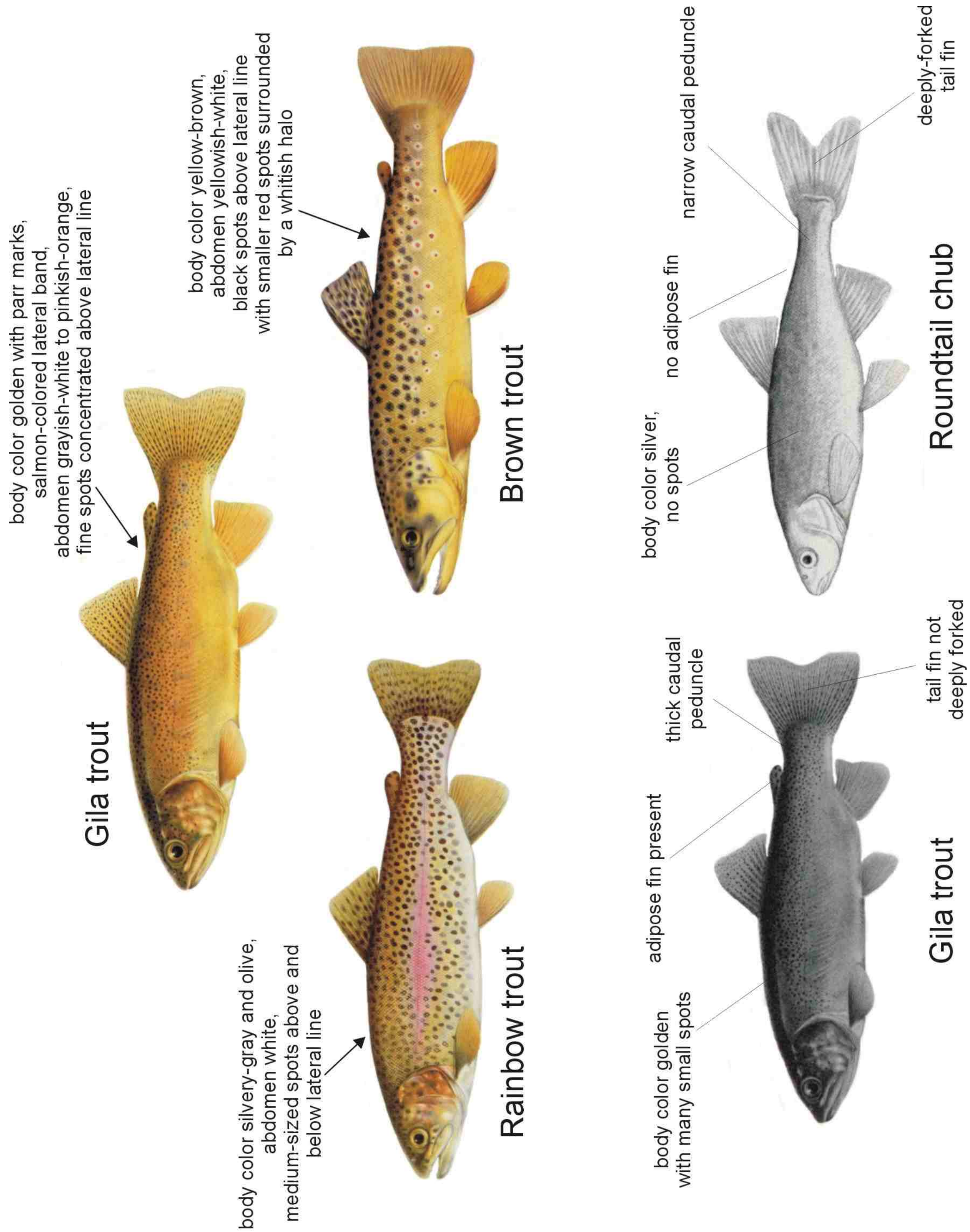
Physical Description

Gila trout is readily identified by its iridescent gold sides that blend to a darker shade of copper on the opercles (Figure 1). Spots on the body of this trout are small and profuse, generally occurring above the lateral line and extending onto the head, dorsal fin, and caudal fin. Spots are irregularly shaped on the sides and increase in size dorsally. On the dorsal surface of the body, spots may be as large as the pupil of the eye and are rounded. A few scattered spots are sometimes present on the anal fin and the adipose fin is typically large and well-spotted. Dorsal, pelvic, and anal fins have a white to yellowish tip that may extend along the leading edge of the pelvic fins. A faint, salmon-pink band is present on adults, particularly during spawning season when the normally white belly may be streaked with yellow or reddish orange. A yellow cutthroat mark is present on most mature specimens. Parr marks are commonly retained by adults, although they may be faint or absent (Miller, 1950; David, 1976).

Gila trout has 135 to 165 scales in the lateral line series, 59 to 63 vertebrae, and 25 to 45 pyloric ceaca in all populations except Spruce Creek, which has a mean of 48 pyloric caeca. Gila trout from Spruce Creek (a tributary to the San Francisco River) and Oak Creek (an extinct population from the Verde River drainage) are known to have basibranchial teeth (David, 1976). The Spruce Creek population is morphologically similar to Apache trout (David, 1976:26-27), but biochemical systematics indicate it is more closely related to Gila trout (Loudenslager et al., 1986; Riddle et al., 1998). Thus, the Spruce Creek population likely represents an evolutionary unit native to the San Francisco River drainage, including Blue River (David, 1998). Gila trout has a diploid chromosome number of 56 and a total arm number of 106 (Behnke, 1970; Beamish and Miller, 1977).

Field characteristics that distinguish Gila trout from other co-occurring nonnative trouts include the golden coloration of the body, parr marks, and fine, profuse spots above the lateral line (Figure 1). These characters differentiate Gila trout from rainbow, brown, and cutthroat trouts. Roundtail chub (*Gila robusta*) is locally confused with Gila trout (Minckley, 1973:101). The two species share a similar distribution, although roundtail chub typically occurs at lower elevations than Gila trout currently occupies. The species may be confused partly because roundtail chub are taken by anglers

Figure 1. Comparison of field characteristics that differentiate Gila trout from co-occurring nonnative brown and rainbow trouts and the native minnow, roundtail chub. All illustrations copyright Joseph R. Tomelleri.



fishing in trout waters. The roundtail chub, a minnow (family Cyprinidae) differs from Gila trout (family Salmonidae) by its body shape and coloration (Figure 1). Roundtail chub lacks an adipose fin and has a narrow caudal peduncle (i.e., the segment of the body to which the tail fin is attached). Also, roundtail chub lack parr marks, golden coloration, yellow cutthroat marks, and salmon-pink band found on Gila trout (Figure 1). Roundtail chub is typically a mottled olive or dark silver color above the lateral line. Body coloration lightens to a light silvery hue below the lateral line (Sublette et al., 1990).

Systematics and Genetic Description

Gila trout is closely related to Apache trout (*Oncorhynchus apache*), with which it comprises a monophyletic group. Gila trout and Apache trout are more closely related to rainbow trout (*O. mykiss*) than they are to cutthroat trout (*O. clarki*). This suggests that Gila and Apache trouts were derived from an ancestral form that also gave rise to rainbow trout (Behnke, 1992; Dowling and Childs, 1992; Utter and Allendorf, 1994; Nielsen et al., 1998; Riddle et al., 1998).

Eight loci have been found diagnostic for distinguishing Gila trout and rainbow trout (Loudenslager et al., 1986; Dowling and Childs, 1992; Leary and Allendorf, 1998). Loci are the specific sites on a chromosome where genes are located. Alleles are different heritable forms of the gene at a given locus. A homozygous locus has two copies of the same allele, whereas a heterozygous locus has two different alleles. Loci that exhibit fixed differences between Gila trout and rainbow trout are termed diagnostic. The eight diagnostic loci between Gila trout and rainbow trout are: *ADH**, *PEPB**, *LDH-C**, *FH-1**, *PGM-I**, *CK-C2**, *GAPDH-4**, and *PGK-2** (Loudenslager et al., 1986; Dowling and Childs, 1992; Leary and Allendorf, 1998). Loci nomenclature follows Shaklee et al. (1990). Analysis of mitochondrial DNA (mtDNA) identified a unique haplotype with a 300 base-pair length increase at the 3' end of the control region that distinguishes Gila and Apache trouts from rainbow trout. Whole mtDNA restriction-site data can be used to distinguish Gila from Apache trout (Riddle et al., 1998). One diagnostic loci, *PEP-A*, was found to be diagnostic between Gila trout and Apache trout (Loudenslager et al., 1986), although subsequent analysis was unable to duplicate these results (Dowling and Childs, 1992).

DISTRIBUTION AND POPULATION STRUCTURE

Historical Range

The historical range of Gila trout can be inferred from early collection records, reports of native ‘mountain’ or ‘speckled’ trout from drainages prior to the introduction of nonnative species, current distributions of trout in the Gila River drainage basin, and distributions of historically co-occurring species. The species historically occurred in mountain stream habitats in Sierra, Grant, and Catron counties in New Mexico and Greenlee, Apache, Graham, Gila, and Yavapai counties in Arizona (Figure 2). Historical distribution of Gila trout in various sub-basins of the Gila River drainage is described below.

Upper Gila River, New Mexico

The earliest documented collections of Gila trout in the upper Gila River drainage were from Main Diamond Creek, made by R.R. Miller in 1939 (UMMZ 137089; museum acronyms follow Leviton et al., 1985). Gila trout was collected from White Creek in 1952 (E. Huntington, MSB 002045) and from Langstroth Canyon and South Diamond Creek in 1953 (J. Sands, MSB 2046 and MSB 2047 & 2050, respectively). In 1975, Gila trout was collected from McKenna Creek (P. Turner, NMSU 3 & 4) and Iron Creek (R. David, NMSU 5). Gila trout was discovered in Whiskey Creek, a tributary to the upper West Fork Gila River, by N.W. Smith in 1992 (D. L. Propst, New Mexico Department of Game and Fish, pers. comm.). Gila *x* rainbow trout hybrids were reported from Black Canyon, Sycamore Canyon, Langstroth Canyon, Miller Spring Canyon, Trail Canyon, upper Mogollon Creek, upper Turkey Creek, and West Fork Mogollon Creek (David, 1976; Riddle et al., 1998).

Early reports indicate that Gila trout was found throughout tributary streams of the upper Gila River drainage. Rixon (1905:50) noted that "Snow Creek drains the Mogollon Mountains in this township (Township 10 South, Range 16 West); it is a large stream, well stocked with mountain trout, but is being rapidly depleted owing to lack of proper protection." Miller (1950:18-21) recounted reports from long-time residents of the region that indicated Gila trout occurred in "all of the Gila headwaters" at the turn of the century. Specific streams mentioned included Gilita Creek, Willow Creek, South Diamond Creek, Black Canyon, Mogollon Creek (including the West Fork Mogollon Creek). Gila trout was reported as occurring in the Middle and West forks of the Gila River and in the main stem of the Gila River downstream to near the Mogollon Creek confluence, approximately 11 km (7 mi) upstream from Cliff.

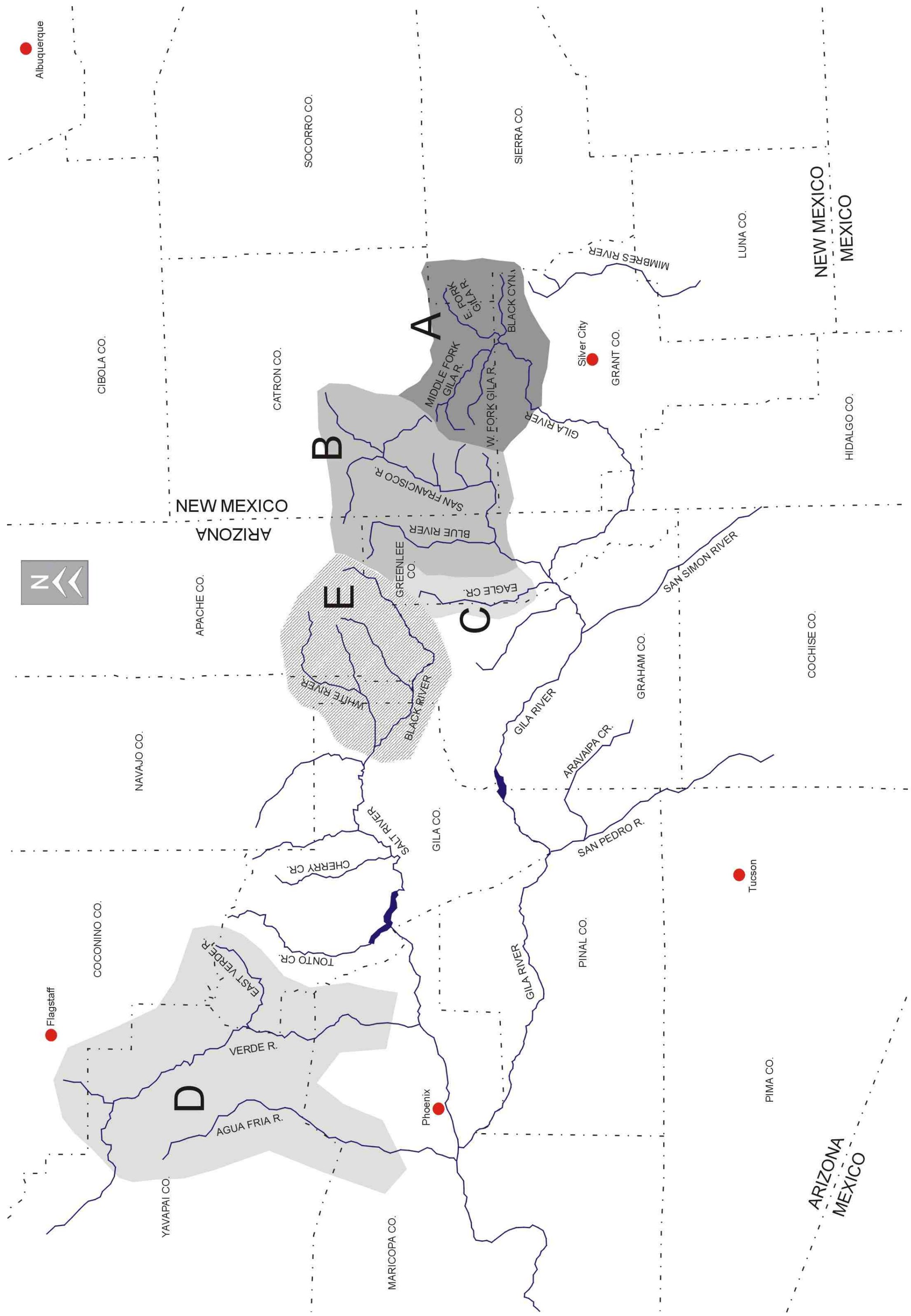
Collections of pure Gila trout and Gila *x* rainbow trout hybrids, reports from around the turn of the century, and the distribution of streams in the upper Gila drainage that currently support trout populations affirm that Gila trout was likely found in perennial streams throughout the drainage upstream from the confluence of Mogollon Creek and the Gila River.

San Francisco River, Arizona and New Mexico

Native trout were reported from the San Francisco River drainage as early as 1885 (Leopold, 1921). Lack of collections prior to introduction of nonnative trout and absence of preserved specimens from many drainages led investigators to consider this native fish variously as Gila trout, Apache trout, or an intergrade between the two. In the following discussion of historical distribution, the native San Francisco River drainage trout is referred to as Gila trout. A discussion of the unique characteristics of the San Francisco River drainage native trout, which shares characteristics of both Gila and Apache trouts (David, 1998), is presented in the definition of lineages.

Leopold (1921:270) reported that the Blue River, a tributary to the San Francisco River in Arizona, was "at the time of settlement in about 1885, stirrup-high in gramma grass and covered with groves of mixed hardwoods and pine. The banks were lined with willows and the river abounded with trout." Native trout were collected from KP Creek, a tributary to the Blue River, in 1904 by F. Chamberlain (Miller, 1950:15-16). This collection was accessioned at the United States National Museum (USNM 39577-79, 41568, and 144278) but was subsequently lost. David (1976) collected and described Gila trout (NMSU 6) from above currently-impassable falls in Spruce Creek, a tributary to the San

Figure 2. Historical distribution of Gila trout. The upper Gila River form (A) is differentiated from the San Francisco River form (B). Eagle Creek (C) and Verde River (D) forms were also likely differentiated, although all that remains of these are hybridized populations. The Apache trout (E) shares some characteristics with the San Francisco form of Gila trout.



Francisco River in New Mexico. Miller (1950:18) reported that Spruce Creek contained a population of Gila trout, with the implication that it was native to that stream. This was inconsistent with the report that the San Francisco River was originally devoid of Gila trout and that the species was stocked into Big Dry Creek, Little Dry Creek, Little Whitewater Creek, Whitewater Creek, and Mineral Creek in 1905 (Miller, 1950:19-20). However, native trout occurred in the Blue River and there are no physical barriers that would have prevented native trout from migrating up into the San Francisco River drainage (Behnke, 1970; David, 1998). Gila *x* rainbow trout hybrid populations were found in several tributaries to the San Francisco River, including Whitewater Creek, Big Dry Creek, Mineral Creek, and Lipsey Canyon (David, 1976; Riddle et al., 1998).

These early reports and collections of a native trout in the San Francisco River drainage and the occurrence of a population of Gila trout in Spruce Creek above currently-impassable falls indicate that Gila trout occurred throughout the drainage in suitable habitats. Historically occupied streams included the Blue River and its tributaries and perennial tributaries of the San Francisco River in New Mexico.

Tributaries to the Gila River, Arizona

Native trout occurred in the Eagle Creek drainage, a tributary of the Gila River in Arizona located west of the San Francisco River drainage (Mulch and Gamble, 1956; Kynard, 1976). The identity of this native trout, now lost through hybridization with rainbow trout, is uncertain (Marsh et al., 1990). Native trout were reported from Oak Creek, a tributary to the Verde River, before the turn of the century (Miller, 1950). Specimens collected from Oak Creek before 1890 (USNM 39577-79, 41568) were ascribed to Gila trout (Miller, 1950:28; Minckley, 1973:62). Native trout were also reported from West Clear Creek, another Verde River tributary (Miller, 1950:28). Trout collected in 1975 from Sycamore Creek, a tributary of Agua Fria, were reported to be Gila *x* rainbow trout hybrids. However, this determination was based solely on examination of spotting pattern (Behnke and Zarn, 1976).

Historical occurrence of Gila trout in the Verde and Agua Fria drainages was inferred by Minckley (1973:61) based on parallel distribution of a morphological form of roundtail chub. At that time Gila trout was the only recognized native trout in the Gila River drainage. Subsequent description of Apache trout demonstrated differentiation of native trout within the Gila River drainage (Miller, 1972). The degree of differentiation of the native trout in the Agua Fria and Verde river drainages is unknown (cf. Minckley, 1973:62) and cannot be resolved because specimens are lacking. However, this native trout was likely very closely related to Gila trout based on lack of long-term hydrologic isolation of the Verde and Agua Fria drainages from the mainstem Gila River.

Currently Occupied Range

The occupied range of Gila trout has fluctuated since 1975, when only five populations of the species were known. Range expansions resulted from establishing new populations by stocking by resource management agencies. Range reductions occurred from local extirpations caused by high-intensity forest fires and hybridization with rainbow trout. Rainbow trout gained access to Gila trout streams through illegal stocking or by natural immigration over what were thought to be barriers to fish movement. By June 2000, Gila trout inhabited approximately 105 km (65 mi) of habitat in 14 streams (Table 1; Gila Trout and Chihuahua Chub Recovery Team, 2000; D. L. Propst, New Mexico

Table 1. Summary and status of streams inhabited by Gila trout as of January 2001 (surviving lineages in bold).

State	County	Stream Name	Drainage	km (mi) of stream inhabited	Origin
NM	Sierra	**Main Diamond Creek**	East Fork Gila River	6.1 (3.8)	**Relict Lineage** Eliminated in 1989, re-established in 1994
NM	Grant	McKnight Creek	Mimbres River	8.5 (5.3)	Replicate of Main Diamond, est. 1970
NM	Grant	Sheep Corral Canyon	Gila River	1.3 (0.8)	Replicate of Main Diamond, est. 1972
NM	Grant	Black Canyon	East Fork Gila River	18.2 (11.3)	Replicate of Main Diamond, est. 1998
NM	Catron	Lower Little Creek	West Fork Gila River	6.0 (3.7)	Replicate of Main Diamond, est. 2000
NM	Catron	Upper White Creek	West Fork Gila River	8.8 (5.5)	Replicate of Main Diamond, est. 2000
NM	Sierra	**South Diamond Creek**[1]	East Fork Gila River	6.7 (4.2)	**Relict Lineage** Eliminated in 1995, re-established in 1997
NM	Catron (Grant)	Mogollon Creek[2]	Gila River	28.8 (17.9)	Replicate of South Diamond Creek, est. 1987
NM	Catron	**Spruce Creek**	San Francisco River	3.7 (2.3)	**Relict Lineage**
NM	Catron	Big Dry Creek	San Francisco River	1.9 (1.2)	Replicate of Spruce Creek, est. 1985
AZ	Gila	Dude Creek	Verde River	3.2 (2.0)	Replicate of Spruce Creek, est. 1999
AZ	Greenlee	Raspberry Creek	Blue River	6.0 (3.7)	Replicate of Spruce Creek, est. 2000
NM	Catron	**Whiskey Creek**	West Fork Gila River	2.6 (1.6)	**Relict Lineage**
NM	Catron	Upper Little Creek	West Fork Gila River	3.0 (1.9)	Replicate of Whiskey Creek, est. 2000

[1] South Diamond Creek includes Burnt Canyon.
[2] Mogollon Creek includes Trail Canyon, Woodrow Canyon, Corral Canyon, and South Fork Mogollon Creek. Portions of the drainage are in Grant County, New Mexico.

Department of Game and Fish, pers. comm.; K. Young, Arizona Fish and Game Department, pers. comm.). The species occurs in Sierra, Grant, and Catron counties, New Mexico, and in Gila and Greenlee counties, Arizona.

Sierra County, New Mexico

Gila trout is found in two drainages in Sierra County, New Mexico: Main Diamond Creek, the type locality; and South Diamond Creek. Main Diamond and South Diamond creeks support relict lineages of Gila trout. Populations in both streams have been dramatically affected by forest fires (Propst et al., 1992). Gila trout were eliminated from Main Diamond Creek in 1989 and from South Diamond Creek in 1995 by high-intensity forest fires. When the Divide Fire (1989) began to burn into the Main Diamond Creek watershed, 566 Gila trout were removed from the stream in an emergency action and taken to Mescalero National Fish Hatchery. Gila trout were repatriated to Main Diamond Creek in 1994. Gila trout were repatriated to South Diamond Creek in 1997, using pure hatchery stock derived from the replicate population in Mogollon Creek. The populations in Main Diamond and South Diamond creeks inhabit approximately 6.1 km (3.8 mi) and 6.7 km (4.2 mi) of stream, respectively (Propst and Stefferud, 1997.

Grant County, New Mexico

Populations of Gila trout have been established in three streams in Grant County: Black Canyon, Sheep Corral Canyon, and McKnight Creek. All of these populations were established from the Main Diamond Creek lineage (see *Definition of Lineages and Population Genetic Structure* below). Initial stocking of Gila trout occurred in 1970 in McKnight Creek, 1972 in Sheep Corral Canyon, and 1998 in Black Canyon (Propst et al., 1992; Gila Trout and Chihuahua Chub Recovery Team, 1999). The population in McKnight Creek inhabits approximately 8.5 km (5.3 mi) of stream and about 1.3 km (0.8 mi) of stream are occupied in Sheep Corral Canyon (Propst and Stefferud, 1997). The population of Gila trout in Black Canyon occupies approximately 18.2 km (11.3 mi) of stream (Brooks and Propst, 1999). McKnight Creek is tributary to the Mimbres River and is not within the historical range of Gila trout.

Catron County, New Mexico

Gila trout occurs in six streams in Catron County: Spruce Creek, Big Dry Creek, Whiskey Creek, White Creek, Mogollon Creek (portions of the stream are in Grant County), and Little Creek. Spruce Creek supports a relict lineage of Gila trout and Whiskey Creek supports a relict population of the species. Big Dry was stocked with Gila trout from Spruce Creek in 1985 (Propst et al., 1992). The upper Mogollon Creek drainage was stocked with Gila trout from South Diamond Creek in 1987. In 1996, the stream was impacted by fire and hybridization with rainbow trout was detected. The stream was renovated in 1996 and restocked in 1997 with pure Gila trout hatchery stock derived from paired matings of pure South Diamond lineage Gila trout salvaged from Mogollon Creek in 1996. A population of Gila trout was discovered in Whiskey Creek in 1992 (Brown et al., 2001). White Creek above the falls was renovated to remove hybrid trout and was stocked with Main Diamond lineage Gila trout in 2000 (pers. comm., D.L. Propst, New Mexico Department of Game and Fish). Upper Little Creek was stocked with Gila trout from Whiskey Creek in April 2000 after the stream was renovated to remove hybrid trout. The lower portion of Little Creek was stocked with Main Diamond lineage

Gila trout in April 2000. Gila trout occupy approximately 3.7 km (2.3 mi) of stream in Spruce Creek and 1.9 km (1.2 mi) in Big Dry Creek. Approximately 28.8 km (17.9 mi) of stream in the upper Mogollon Creek drainage are occupied by Gila trout (Propst and Stefferud, 1997). Whiskey Creek supports Gila trout in approximately 2.2 km (1.6 mi) of stream. Gila trout occupy about 8.8 km (5.5 mi) of stream in White Creek and 9.0 km (5.6 mi) in Little Creek.

McKenna Creek and Iron Creek were thought to support relict lineages of pure Gila trout (U.S. Fish and Wildlife Service, 1993). However, rainbow trout introgression was discovered in these two populations during comprehensive, range-wide allozymic analyses of the species in 1997 (Riddle et al., 1998; Leary and Allendorf, 1998). Rainbow trout was likely introduced into these streams once or twice prior to the 1950s (Leary and Allendorf, 1998; Riddle et al., 1998). Both Iron Creek and McKenna Creek populations were replicated before it was known that they were hybridized with rainbow trout. A replicate population of the hybridized Iron Creek population was established in White Creek in 1983 and in Sacaton Creek in 1990. Similarly, a replicate population of the hybridized McKenna Creek population was established in Little Creek in 1982. Gila *x* rainbow hybrids remain in Iron Creek, McKenna Creek, and Sacaton Creek. Hybrid trout were removed from Little Creek in 1999 and from White Creek in 2000 to reclaim the two streams for Gila trout.

Yavapai County, Arizona

Gila trout formerly occurred in Gap Creek, a tributary of the Verde River in the Cedar Bench Wilderness, Prescott National Forest. Gap Creek was stocked with Gila trout from Main Diamond Creek in 1974 (Minckley and Brooks, 1985). The population inhabited up to about 2.0 km (1.2 mi) of high-gradient stream where the only available habitat was deep scour pools (Warnecke, 1987). Peak flows every year typically flushed Gila trout downstream, where they would remain concentrated in several pools. Management agencies annually collected and redistributed Gila trout to upstream habitats. The population of Gila trout in Gap Creek gradually declined, indicating that the high gradient habitat and extremely variable flow regime were not suitable habitat for the species. Detection of only six fish in separate, isolated pools in August 1990 indicated that the population did not persist in the stream (Propst et al., 1992). The population is now considered extirpated.

Gila County, Arizona

Dude Creek, a tributary of the East Verde River near Payson, was stocked with Gila trout from Spruce Creek in 1999 (Gila Trout and Chihuahua Chub Recovery Team, 2000). A high-intensity forest fire in 1989 eliminated an existing nonnative trout fishery and the stream remained fishless until it was stocked with Gila trout. Gila trout currently occupy approximately 3.2 km (2.0 mi) of stream in Dude Creek (Gila Trout and Chihuahua Chub Recovery Team, 2000; K. Young, Arizona Fish and Game Department, pers. comm.).

Greenlee County, Arizona

Raspberry Creek was stocked with 113 age 0 Gila trout in November 2000 (K. Young, Arizona Fish and Game Department, pers. comm.). The stocked fish were produced from wild Spruce Creek Gila trout that were spawned at Mescalero National Fish Hatchery. Raspberry Creek was fishless prior to stocking with Gila trout. The stream is tributary to Blue River.

Definition of Lineages and Genetic Population Structure

Originally (ca. 1975), five relict lineages of Gila trout were believed to exist (U.S. Fish and Wildlife Service, 1993). These relict lineages consisted of naturally-occurring populations of Gila trout that were isolated from each other in small headwater streams. The five original, presumed pure lineages were: Main Diamond, South Diamond, Spruce, Iron, and McKenna.

Although the McKenna and Iron lineages have phenotypic characteristics of Gila trout, they were recently found to be hybridized with rainbow trout. Introduction of rainbow trout likely occurred prior to 1950 in both of these streams (Leary and Allendorf, 1998). The McKenna Creek population was reported in 1964 (Regan, 1966; Hanson, 1971) and the Iron Creek population was found in 1975 (David, 1976). Rainbow trout introgression in these two populations was not detected until after both had been replicated. Hybrid Iron Creek and McKenna Creek populations are not pure Gila trout and do not contribute to recovery of the species. Therefore, they are no longer a component of recovery of Gila trout.

The Main Diamond, South Diamond, and Spruce lineages showed no indication of hybridization with rainbow trout in recent allozyme analyses (Leary and Allendorf, 1998). A population of trout was discovered in Whiskey Creek in 1992 and was subsequently confirmed to be genetically pure Gila trout (Leary and Allendorf, 1998). The Main Diamond, South Diamond, Whiskey Creek, and Spruce lineages are considered pure Gila trout.

There is considerable genetic variation among the Main Diamond, South Diamond, and Spruce Creek populations of Gila trout (Leary and Allendorf, 1998). No rare alleles were found in the Whiskey Creek population. However, only a small number of loci have been examined. This population represents the only pure lineage from the West Fork Gila River. The unique genetic material contained in each of these four populations distinguishes them as distinct lineages. The four lineages encompass the breadth of local adaptation and evolutionary potential represented by known genetic variation that presently exists within the species.

The Spruce Creek lineage contains a unique, diagnostic allele (*PGM-1*null*) at a frequency of 1.000 that distinguishes it from the other three lineages. The Spruce Creek lineage also has a fixed mtDNA haplotype that is not found in the upper Gila River drainage lineages, which indicates that Gila trout in the San Francisco and upper Gila River drainages were isolated from each other for some time (Riddle et al., 1998). The Main Diamond lineage also contains a unique allele (*sAAT-1*null*) as does the South Diamond lineage (*sMEP-2*85* and *sMEP-2*115*). Two other alleles (*sMDH-B1,2*74* and *sMEP-1*100*) are found at variable frequencies in the three upper Gila River drainage lineages (Leary and Allendorf, 1998). The Whiskey Creek lineage is not known to contain unique alleles. The Whiskey Creek lineage is either homozyous or has allelic frequencies intermediate between Main Diamond and South Diamond at seven variable loci (Leary and Allendorf, 1998).

HABITAT

Habitat Characteristics

Habitat of Gila trout consists of perennial montane streams ranging from 1,660 m (5,400 ft) to over 2,800 m (9,200 ft) elevation (Propst and Stefferud, 1997). Habitats suitable for Gila trout are located in the provisionally-defined Aquatic Ecoregions 1 and 2 (Jacobi et al., 1997). Suitable stream habitat within the range of the species is situated between about 33° to near 35° north latitude and 107° 45' to near 112° 15' west longitude.

Streams with suitable habitat for Gila trout are found in coniferous and mixed woodland, montane coniferous forest, and subalpine coniferous forest (Dick-Peddie, 1993). Coniferous and mixed woodland vegetation occur at lower elevations and on southern exposures within the range of Gila trout. Dominant tree species in the coniferous and mixed woodland are piñon (*Pinus edulis*), juniper (*Juniperus* sp.), and oak (*Quercus* sp.). Montane coniferous forest occurs up to about 3,048 m (10,000 ft) elevation. Below 2,591 m (8,500 ft) elevation, this forest is characteristically dominated by ponderosa pine (*Pinus ponderosa*). Above about 2,438 m (8,000 ft) elevation Douglas-fir (*Pseudotsuga menziesii*), white fir (*Abies concolor*), blue spruce (*Picea pungens*) and aspen (*Populus tremuloides*) are common. Subalpine coniferous forest is characterized by Engelmann spruce (*Picea engelmannii*) and corkbark fir (*Abies lasiocarpa*) and is generally found from about 2,896 m (9,500 ft) elevation to timberline (Dick-Peddie, 1993).

Riparian habitats include the montane riparian vegetation type described by Dick-Peddie (1993:148-151, 159) and the arctic-boreal and cold-temperate riparian communities of Brown (1982). Fourteen of the 18 series described for the montane riparian vegetation type are found in habitats of Gila trout (Dick-Peddie, 1993:159). These series are: Willow; Willow-Mountain Alder; Willow-Dogwood; Blue Spruce; Aspen; Aspen-Maple; Boxelder; Alder; Narrowleaf Cottonwood; Narrowleaf Cottonwood-Mixed Deciduous; Broadleaf Cottonwood; Broadleaf Cottonwood-Mixed Deciduous; and Sycamore.

Hydrology

Long-term discharge data from streams inhabited by or suitable for Gila trout are lacking. Short-term or single point-in-time measurements of stream discharge have been made by numerous investigators (e.g., Regan, 1966; Mello and Turner, 1980; Rinne, 1980; McHenry, 1986; Pittenger, 1986; Propst and Stefferud, 1997). Rinne (1980) reported discharge measurements from March through April 1978 from a gaging station on McKnight Creek. Pittenger (1986) measured discharge of McKnight Creek during three two-week periods that encompassed spring runoff (May-June 1985), early summer base flow (June 1984), and summer thunderstorm runoff conditions (August 1984). Despite this lack of long-term discharge data from headwater streams, generalizations regarding flow variability can be made based on gage sites located at lower elevations on larger streams that receive flow from tributary headwater habitats.

The mean return interval of bankfull discharge in the upper Gila River drainage basin is 1.3 years, with a range of 1.0 to 1.6 (Knight et al., 1999). Bankfull discharge is defined as the stream stage where flooding begins, which is associated with the point where the stream is just about to flow out of its banks and onto the floodplain (Rosgen, 1996). Bankfull flow is also associated with the dominant channel-forming discharge (Dunne and Leopold, 1978:208-209), which transports the majority of available sediment (Wolman and Miller, 1960). Bankfull discharge is an important hydrologic variable in formation and maintenance of aquatic habitat features.

Stream flow in habitat of Gila trout is characterized by a snowmelt-dominated hydrograph (Figure 3). The hydrographs in Figure 3 show mean monthly discharge at three stations located on major streams in the vicinity of the range of Gila trout in New Mexico. Although these stations are located below the elevation range of habitat suitable for Gila trout and discharges are orders of magnitude higher, the data represent the annual pattern of discharge in headwater streams occupied by the species. Snowmelt runoff typically begins in February, peaks in March, and then gradually decreases through May. Base flow conditions prevail in June and into July. Mean monthly discharge characteristically increases in July through September coincident with runoff from convectional summer thunderstorms. Sporadic periods of runoff from winter rains or mid-season snowmelt often results in flows slightly elevated above base level in December and January (Figure 3).

This general pattern of stream discharge is apparent over years of record; however, any year may show substantial deviation from this average annual hydrograph. In fact, high stream discharge variability is a defining characteristic of the environment to which Gila trout has adapted. The extreme variability of stream discharge in habitat of Gila trout is exemplified by fluctuations in total annual discharge of the Gila River from 1928 through 1997 (Figure 4A). Total annual discharge during wet years may exceed that of subsequent and ensuing dry years by as much as 500%. Although the shape of the annual hydrographs may be similar, actual discharge may vary by an order of magnitude or more between wet and dry years (Figure 4B).

During low-flow years, marginal habitats may become too warm to support trout or surface flow may cease and stream segments may dry. Pool depth may diminish to the extent that winter mortality of trout is greatly increased. Large magnitude flood events during high flow years may scour stream channels and eliminate year classes of trout. These frequent, recurring extremes in flow conditions are a basic element of the relatively harsh environment that distinguishes habitat of Gila trout from the typical trout streams of more northern latitudes.

Water Quality

Water quality in habitat of Gila trout is generally characterized by high dissolved oxygen concentration, low turbidity and conductivity, low levels of total dissolved solids, near-neutral *p*H, and low conductivity (Hanson, 1971). Localized, and radical, changes in water quality may occur with removal of canopy shading and introduction of ash and sediment following forest fires (e.g., Baker, 1988; Novak, 1988:37-43; Amaranthus et al., 1989; Rinne, 1996; Gresswell, 2000). For example, a maximum suspended sediment concentration of 10,140 mg/l was recorded in Main Diamond Creek in the year following a wildfire in that watershed (Wood and Turner, 1992). Some streams that provide potentially-suitable habitat for Gila trout have degraded water quality resulting from removal of riparian vegetation and nutrient input associated with ongoing or historical heavy livestock use or other land management practices (e.g., Canyon Creek, Trout Creek).

Figure 3. Mean monthly discharge (cubic feet per second, cfs) at three USGS stream gauging stations in the vicinity of the range of Gila trout. Error bars above the columns represent the upper 95% confidence interval of the mean.

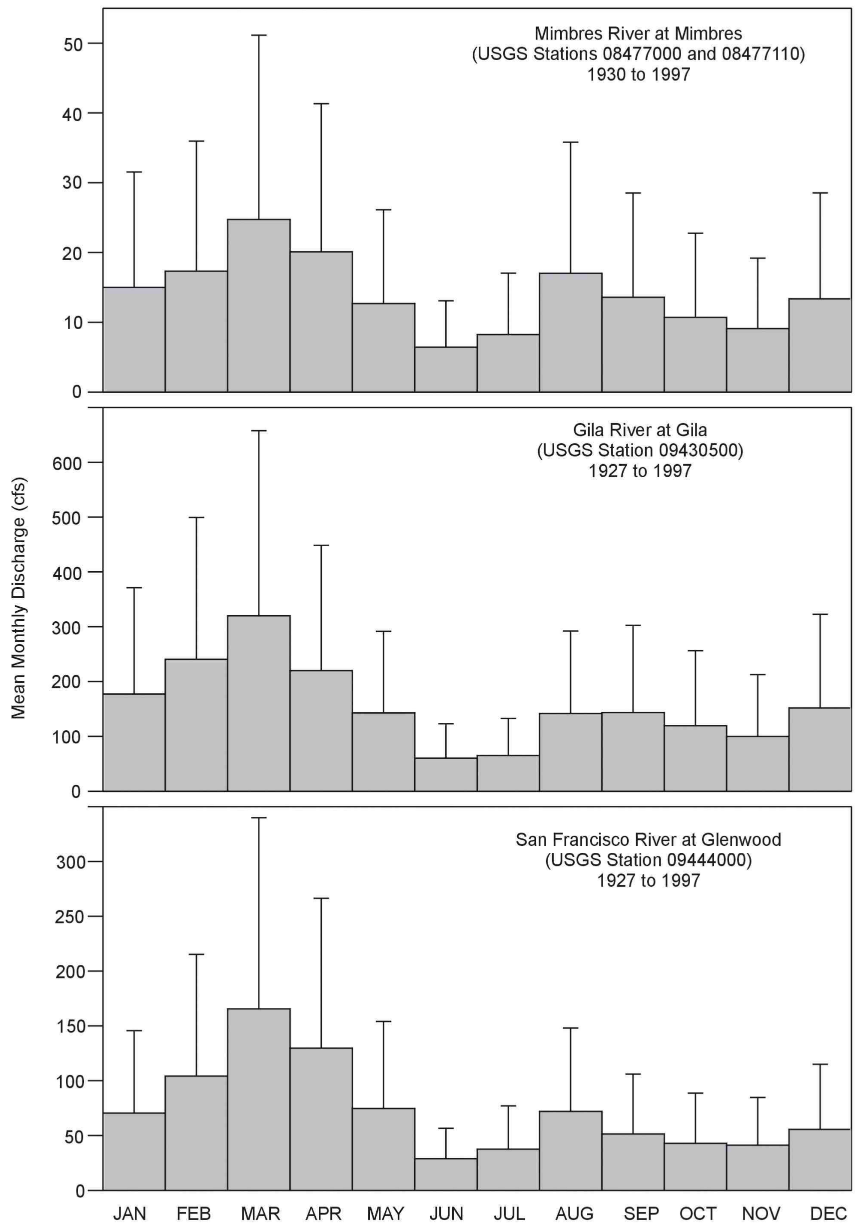
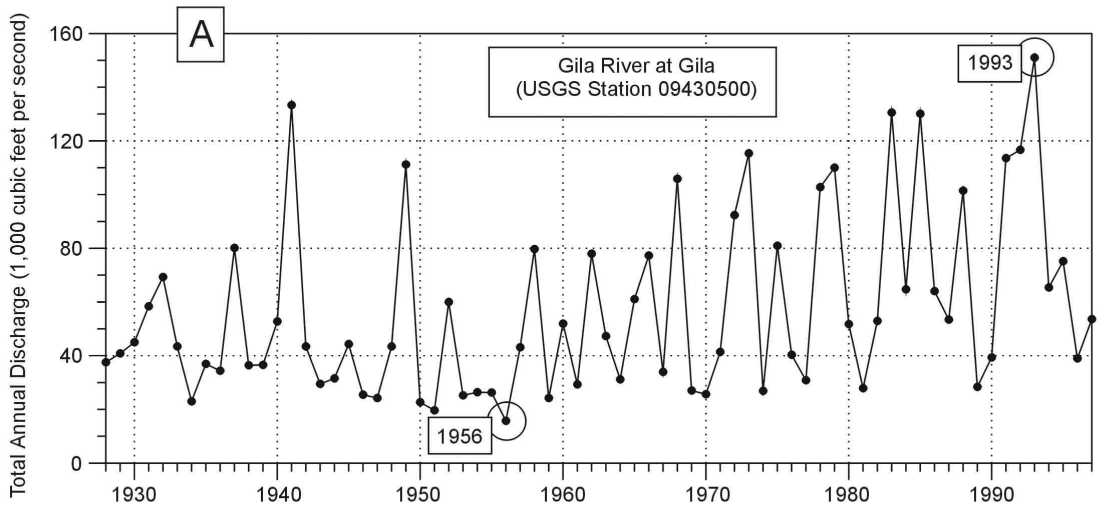
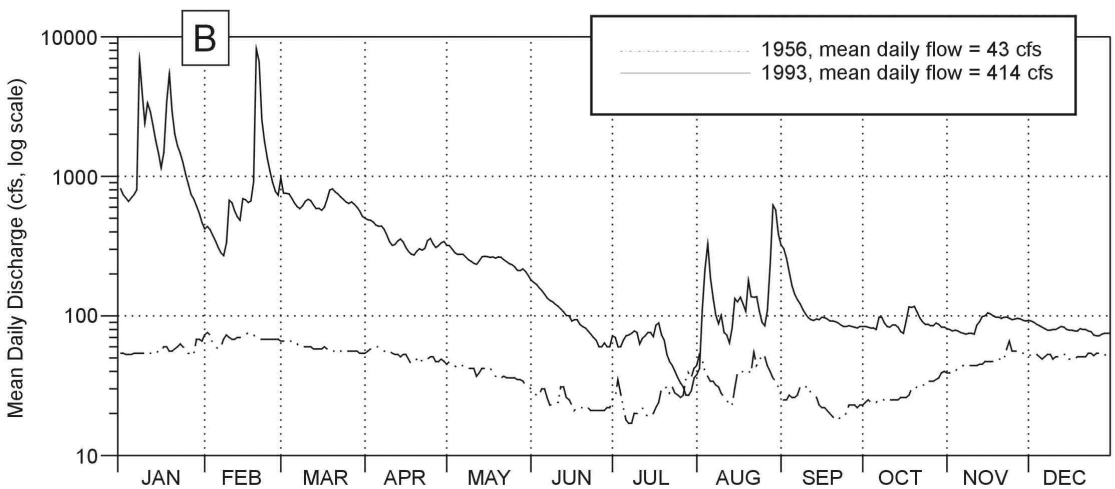


Figure 4. Total annual discharge of the Gila River near Gila (A) and comparison of the annual hydrograph at the same station for a dry year with that of a wet year (B).





Maximum water temperatures in habitat of Gila trout typically do not exceed about 25ºC (77ºF). Lee and Rinne (1980) found that Gila trout could tolerate temperatures up to 27 C (81ºF) for up to two hours. A maximum water temperature of 22.4 C (72.3ºF) was recorded at McKnight Creek in 1989 (J.A. Stefferud, U.S. Forest Service, pers. comm.). Pittenger (1986) reported a maximum diel fluctuation in water temperature of 10ºC (18ºF) in McKnight Creek on 10 June 1985 (8ºC to 18ºC [46.4ºF 64.4ºF]).

Stream Morphology

Channel gradient varies widely in habitat of Gila trout, from near 1% to over 14% (McHenry, 1986; Propst and Stefferud, 1997). Quantitative data on channel pattern, bankfull channel dimensions, and substrate characteristics of streams within the range of Gila trout are sparse or lacking. Average substrate composition in spawning habitat of Gila trout in Main Diamond, South Diamond, and McKnight creeks consisted of 6.6% silts, clays, and very fine to coarse sands (less than 1 mm diameter), 14.4% very coarse sand (1 to 2 mm), 27.4% very fine to medium gravels (2 to 9 mm), 20.1% medium to coarse gravels (9 to 18 mm), 17.8% coarse gravels (18 to 38 mm), 6.9% very coarse gravels (38 to 63 mm), and 6.7% cobbles (64 to 256 mm; data summarized from Rinne, 1980; particle diameter class names adapted from Rosgen, 1998).

Stefferud (1995a, 1995b) reported Rosgen stream types A1, A2, B3, B4 and D4 for several streams within the range of Gila trout (White Creek, Langstroth Canyon, West Fork Gila River, Mogollon Creek, South Fork Mogollon Creek, Trail Canyon, and Corral Canyon). However, measured values for entrenchment ratio, bankfull width:depth ratio, and sinuosity were not reported for any stream, indicating that stream classification was based on qualitative evaluation rather than field measurements. Knight et al. (1999) reported stream types B4, B4c, C3, C4b, E3b, and F4 in habitats within the range of Gila trout, based on detailed field measurements. Basin-wide habitat typing was conducted on White Creek (Stefferud, 1994). This analysis found step-run habitat to be the dominant type in a reach of White Creek that had a channel slope of 4.6%. Width:depth ratio in McKnight Creek ranged from 7.6 to 51.7 (Medina and Martin, 1988). Width measurements were made at the "top" of the channel, which corresponds approximately with bankfull width.

Pool area relative to riffle area is variable among streams. Stefferud (1994) reported a pool:riffle ratio in White Creek of 0.26:1 based on length and 0.30:1 based on area. Nankervis (1988) found pool:riffle ratios ranging from 0.23:1 to 0.28:1 in Main Diamond Creek, while values ranging from 0.05:1 to 1.17:1 were reported for numerous streams by Mello and Turner (1980). Rinne (1981) found significantly greater mean and maximum depths in pools created by log structures compared to natural pools. Log structures have been constructed in numerous streams within the range of Gila trout, including McKnight Creek, Main Diamond Creek, South Diamond Creek, Sheep Corral Canyon, White Creek, Beaver Creek and others (Regan, 1966; Rinne, 1981; Stefferud, 1994). Mean and maximum water depth has been reported by several investigators but measurements were not recorded relative to bankfull stage or any other consistent elevation (Rinne, 1978; Rinne, 1981; Stefferud, 1994). Therefore, meaningful comparisons and generalizations about variation in depth are not possible.

McHenry (1986) reported cover values ranging from 10.7% to 45.8% in seven streams occupied by Gila trout or Gila *x* rainbow hybrids, while Nankervis (1988) reported cover values ranging from 13.7% to 21.3% in Main Diamond Creek. Cover was defined as areas providing refuge from current velocity, predators, and light; and included undercut banks, woody debris, root wads, deep pools, overhanging vegetation, aquatic macrophytes, rock shelter, and areas of surface turbulence (McHenry, 1986:23; Nankervis, 1988:44).

Aquatic Macroinvertebrates

Aquatic macroinvertebrate community composition in habitats of Gila trout has been reported by numerous investigators (e.g., Regan, 1966; Hanson, 1971; Mello and Turner, 1980; Mangum, 1981, 1984, and 1985; McHenry 1986; Pittenger, 1986; Jacobi, 1988; Van Eimeren, 1988). Benthic macroinvertebrate communities are typically dominated by Diptera (true flies), Ephemeroptera (mayflies), and Trichoptera (caddisflies). Plecoptera (stoneflies), Coleoptera (beetles), and other orders typically constitute less than 10% of the number of aquatic benthic macroinvertebrates in habitats of Gila trout. Density of benthic macroinvertebrates varies considerably among streams and within streams between years. Aquatic macroinvertebrate densities ranging from 69 to 1,934/m^2 (742 to 20,810/ft^2) have been reported (Regan, 1964; Hanson, 1971; Mello and Turner, 1980; Mangum, 1984; Mangum, 1985; McHenry, 1986; Van Eimeren, 1988).

Trophic Structure and Trout Biomass

Productivity in streams within the range of Gila trout has not been directly measured. In general, allochthonous primary production exceeds autotrophic production in headwater streams (Vannote et al., 1980). This results in a ratio of gross primary productivity to community respiration of less than one in headwater stream habitats. Allochthonous primary production is the input of organic matter into a stream that is derived from an external source, such as leaves falling into the stream from riparian vegetation. Autochthonous production refers to organic matter produced within the stream itself through the process of photosynthesis (Wetzel, 1983). The relative importance of allochthonous versus autochthonous production is largely a function of the degree of stream shading by riparian vegetation or topography. Also, there may be seasonal shifts in the relative importance of the two forms of production (Minshall, 1978).

Benthic macroinvertebrate communities in headwater stream ecosystems are typically dominated by two functional feeding groups: shredders and collectors (Cummins and Klug, 1979). The shredder feeding group forage on coarse particulate organic material, such as leaves, conifer needles, and scales of conifer cones. Particulate materials that have been colonized by microorganisms are preferentially selected. Foraging action by macroinvertebrates in the shredder feeding group produce fine particulate organic matter. This material, together with fine particulate and dissolved organic matter produced by microbial decomposition and mechanical breakdown, is consumed by the collector feeding group. The collector feeding group consists of macroinvertebrates that gather or filter fine or dissolved particulates. These organisms, together with terrestrial invertebrates that fall into the stream or that metamorphose from aquatic larvae, constitute the primary food source of Gila trout (Van Eimeren, 1988).

Fish community structure in streams within the range of Gila trout is typically characterized by low diversity. In most streams, trout are the only fishes present. However, historically Gila trout coexisted with other native fishes. Native fish species that may occur in habitats of Gila trout include longfin dace (*Agosia chrysogaster*), roundtail chub (*Gila robusta*), speckled dace (*Rhinichthys osculus*), desert sucker (*Catostomus clarki*), and Sonora sucker (*Catsotomus insignis*). McHenry (1986) reported Gila trout biomass ranging from 2.6 to 20 grams/m^2 (23.2 to 178.4 lbs/ac) in Main Diamond, South Diamond, McKenna, Iron, Spruce, McKnight, and Big Dry creeks. Biomass of Gila trout is comparable to and often higher than that of other western trouts (Platts and McHenry, 1988).

Essential Habitat Elements

This section describes those habitat elements that are most essential for support and persistence of populations of Gila trout. The section is organized by habitat needed for discrete life stages of Gila trout, following Behnke (1992:24-50). The sensitivity of each life stage to changes in essential habitat elements and tolerance to take of individuals is discussed.

Spawning Habitat

Spawning habitat is defined as areas suitable for deposition and fertilization of eggs and development of embryos of Gila trout. The egg and embryo life stages are completed in the substrate of the stream. Essential habitat elements for these life stages center on maintenance of adequate dissolved oxygen concentration, circulation of fresh water in the stream substrate, and absence of gametes of rainbow trout available for fertilization of Gila trout eggs.

Suitable substrate composition for development of eggs and embryos is characterized by approximately 7% or less fines (particles less than 1 mm [0.04 in] diameter) by weight (Rinne, 1980). Coarse sands and gravels ranging from 1 mm (0.04 in) to 18 mm (0.7 in) diameter compose approximately 60% of the substrate in suitable habitat for eggs and embryos (Rinne, 1980). Intragravel flow and substrate conditions that provide dissolved oxygen concentrations at or near 100% saturation are optimal for development of eggs (Piper et al., 1983:192). This typically translates to dissolved oxygen concentrations of nine to 12 mg/l (ppm) or higher (Behnke, 1992:31). Minimum intragravel water flow for development of eggs has not been quantified for Gila trout. However, stagnant or still water conditions would certainly result in elevated or complete egg mortality. Absence of rainbow trout is another essential element of spawning habitat. Rainbow and Gila trouts have concurrent spawning periods. Therefore, rainbow trout may fertilize eggs of Gila trout and vice versa, resulting in hybrid offspring.

Populations of Gila trout may withstand losses of individual redds and even whole year classes that may result from siltation, low flows, and scouring floods (e.g., Nankervis, 1988:48). However, excessive siltation, low intragravel dissolved oxygen concentrations, and inadequate intragravel water circulation that persist over two or more years may result in population decline and eventual extirpation. Populations of Gila trout are extremely sensitive to the presence of rainbow trout. Even the occurrence of a few individual *O. mykiss* is likely to result in the loss of a population of Gila trout through genetic introgression.

Nursery and Rearing Habitat

Nursery and rearing habitats are areas used by larval and fry life stages of Gila trout. Although no studies have been done on habitat use by this life stage of Gila trout, generalizations can be made based on characteristics of related trout species. Suitable nursery habitat for trout includes areas with slow current velocity such as stream margins, seeps, shallow bars, and side channels (Behnke, 1992:25). Threshold current velocities, water depths, water temperatures, and substrate conditions that define nursery and rearing habitat of Gila trout are not known. Similarly, threshold values for the quantity of nursery and rearing habitat required to maintain populations of Gila trout are not known. Survival rate of Gila trout larvae and fry may be influenced by characteristics of the annual hydrograph as well. Low flows during emergence from the egg and early growth of larval trout may result in strong year classes (Behnke, 1992:25), as may constant, elevated flows during summer (D. L. Propst, New Mexico Department of Game and Fish, pers. comm.). Absence of predation by nonnative trouts, particularly brown trout, is another essential element of nursery and rearing habitat.

As with spawning habitat, populations of Gila trout can withstand impacts to nursery and rearing habitat of short duration and if the population has an existing size structure that will ensure reproduction in subsequent years. Populations of Gila trout may be able to withstand low levels of predation by brown trout. However, predation effects exerted over several consecutive years, coupled with population expansion of brown trout, may result in extirpation of Gila trout from a stream.

Subadult and Adult Habitat

Subadult and adult habitats are defined as areas suitable for survival and growth of these life stages of Gila trout. Subadults are immature individuals generally less than 150 mm (6 in) total length and adults are mature individuals typically greater than or equal to 150 mm (6 in) total length (Propst and Stefferud, 1997). The quantity and quality of adult habitat typically limits population biomass of trout (Behnke, 1992:25). Essential elements of subadult and adult habitat relate principally to channel dimensions, cover, and hydrologic variability. Absence of competition with brown trout for foraging habitat is also an essential element of subadult and adult habitat.

Subadult Gila trout occur primarily in riffles, while adults are found mainly in pools (Rinne, 1978). Cover is an important component in both riffle and pool habitat (Hanson, 1971; Rinne, 1981, McHenry, 1986). Size of Gila trout is positively correlated with maximum pool depth and individuals larger than 200 mm (8 in) total length are typically found in pools that are 0.5 m (1.6 ft) deep or deeper (Rinne, 1978; Rinne, 1981). Pool depth in suitable habitats is generally 0.3 m (1 ft) or greater. Areas within pools with current velocity ranging from 0 to 0.1 m/sec (0 to 0.3 ft/sec) adjacent to areas of swifter flow provide locations where trout can rest and obtain food from drift (Behnke, 1992:25). Large woody debris has been identified as an important component of pool habitat, both in terms of pool formation and providing cover (Stefferud, 1994).

Variation in stream flow has been identified as a major factor affecting subadult and adult population size (McHenry, 1986; Turner, 1989; Propst and Stefferud, 1997). In particular, high flow events often cause marked depression in population size. These events result in short-term, radical changes in habitat conditions, primarily in flow velocity. Because most habitats of Gila trout are characterized by relatively narrow floodplains, the forces associated with high flow events are concentrated in and immediately adjacent to the bankfull channel. High stream flow velocities and shear stresses cause channel scouring and displacement of fish downstream, often into unsuitable habitats (Rinne, 1982).

Changes in mortality rate of adult trout as the result of sport fishing depends upon fishing pressure, allowable number of fish that can be removed from the stream, length limit restrictions, and type of angling gear. Native trouts are typically quite susceptible to angling (Behnke and Zarn, 1976; Behnke, 1979; Turner and McHenry, 1985).

Populations of Gila trout are particularly sensitive to impacts that cause reductions in cover and pool depth. These elements of subadult and adult habitat are major components that influence biomass and size structure of populations of Gila trout. Cover includes overhanging woody and herbaceous riparian vegetation, undercut banks, woody debris in the stream channel, boulders, and deep water. Populations of the species may be dramatically affected by variation in stream flow (McHenry, 1986; Turner, 1989; Propst and Stefferud, 1997). Impacts to habitat of Gila trout that increase variability of stream flow, such as changes in watershed condition, can result in population decline and extirpation.

Populations of Gila trout may vary in sensitivity and response to removal of adult fish. Populations with high densities and reduced growth rates due to crowding may benefit from limited harvest of adult fish. For example, biomass and condition of Gila trout increased following experimental removal of fish from a section of Main Diamond Creek in 1986 to 1987 (Nankervis, 1988). However, populations with low density and relatively few adult fish may be negatively affected by angling harvest. Brown et al. (2001) found that simulated catch-and-release angling mortality of adult Gila trout of 5% to 15% per year had no effect on population viability.

Overwintering Habitat

Overwintering habitat is defined as areas used by Gila trout that afford shelter during periods of water temperature minima generally from November through February. Rinne (1981) and Propst and Stefferud (1997) indicated the importance of pool habitat for overwinter survival of Gila trout. However, the relationships between pool depth and survival rate have not been elucidated.

Essential elements of overwintering habitat are deep water with low current velocity and protective cover (Behnke, 1992:26). Examples include deep pools with cover such as boulders or root wads or deep beaver ponds. Access to larger main stem habitats from headwater streams may be an important function of overwinter survival where a perennial surface water connection between streams exists.

Similar to subadult and adult habitat, populations of Gila trout may be quite sensitive to impacts that result in reduced cover and pool depth. Creation of barriers to fish movement that may prevent fish from accessing overwintering habitat may also result in impacts to populations of Gila trout.

LIFE HISTORY, ECOLOGY, AND POPULATION DYNAMICS

Reproduction and Fecundity

Spawning of Gila trout occurs mainly in April (Rinne, 1980; D. L. Propst, New Mexico Department of Game and Fish, pers. comm.). Spawning begins when temperatures reach about 8 C (46°F), but day length may also be an important cue. Stream flow is apparently of secondary importance in triggering spawning activity (Rinne, 1980). Female Gila trout typically construct redds in water six to 15 cm (2.4 to 6 in) deep within five m (16 ft) of cover. Nests are three to four cm (1.2 to 1.6 in) deep in fine gravel and coarse sand substrate (i.e., particle size ranging from 0.2 to 3.8 cm [0.08 to 1.5 in] diameter). Redd size varies from less than 0.1 to 2.0 m^2 (1.1 to 21.5 ft^2). Spawning activity typically occurs between 1300 and 1600 hours. Rinne (1980) noted one pair of fish normally occurred over a redd and spawning behavior was typical of other salmonids.

Females reach maturity at age II to age IV (Nankervis, 1988; D. L. Propst, New Mexico Department of Game and Fish, pers. comm.), with a minimum length of about 130 mm (5 in) reported for mature fish (Nankervis, 1988; Propst and Stefferud, 1997). However, most individuals are mature at a length of 150 mm (6 in) or greater (Propst and Stefferud, 1997). Males typically reach maturity at age II or III.

Fecundity is dependent upon body size and condition (Behnke and Zarn, 1976; Behnke, 1979). Nankervis (1988) described the relationship between total length (*TL*) and ova number (*F*) as:

$\log_{10}F = (-3.0738) + (2.3305) \times (\log_{10}TL)$ in Main Diamond Creek, $r^2 = 0.92$;

and

$\log_{10}F = (-3.5443) + (2.6078) \times (\log_{10}TL)$ in McKnight Creek, $r^2 = 0.92$.

Gila trout had an average of 2.54 ova per gram of body weight (72 ova/oz) in Main Diamond Creek and 3.33 ova per gram of body weight (94 ova/oz) in McKnight Creek (Nankervis, 1988). Behnke and Zarn (1976) reported a general figure of 2.20 ova per gram of body weight (62 ova/oz) for native trouts. Brown et al. (2001) reported individual fecundity of about 62 for Gila trout 100 to 150 mm total length and 197 for Gila trout greater than 150 mm total length.

Growth, Somatic Statistics, Survivorship, and Longevity

Fry (20 to 25 mm [0.8 to 1.0 in] total length) emerge from redds in 56 to 70 days (Rinne, 1980). By the end of the first summer, fry attain a total length of 70 to 90 mm (2.7 to 3.5 in) at lower elevation streams and 40 to 50 mm (1.6 to 2.0 in) at higher elevation sites (Rinne, 1980; Turner, 1986). Growth rates are variable, but Gila trout generally reach 180 to 220 mm (7.1 to 8.7 in) total length by the end of the third growing season in all but higher elevation streams (Table 2).

Table 2. Mean total length (mm) at age of Gila trout from selected streams.

Stream	Year	Age								
		I	II	III	IV	V	VI	VII	VIII	IX
Sheep Corral Canyon	1983[2]	77[1]	138	204	243	--	--	--	--	--
South Diamond Creek	1975[2]	85	143	219	303	337	--	--	--	--
"	1983[2]	69	124	182	223	256	--	--	--	--
Spruce Creek	1983[2]	77	135	180	250	--	--	--	--	--
McKnight Creek	1976[2]	102	179	235	290	--	--	--	--	--
"	1983[2]	73	131	182	223	267	--	--	--	--
"	1987[3]	63	128	158	190	206	248	274	--	--
"	1988[3]	69	119	162	185	204	--	--	--	--
Main Diamond Creek	1969[4]	45	86	120	157	163	--	--	--	--
"	1986[5]	51	81	97	126	142	--	--	--	186
"	1987[5]	53	88	113	137	146	167	214	148	--
"	1988[3]	44	84	107	125	142	152	170	--	--

[1] Back-calculated mean total length at annulus (mm)
[2] Turner (1986)
[3] Turner (1989)
[4] Hanson (1971)
[5] Nankervis (1988)

Condition factor of Gila trout was found to vary from 0.4235 to 1.2149 in a data set that included 11 streams and that spanned seven years (Propst and Stefferud, 1997). Propst and Stefferud (1997) also reported length-weight relationships for this data set using the function:

$$W = (aL^b) \times (10^{-6})$$

where W = mass in grams, a = ordinate intercept, L = total length in mm, and b = slope of the regression line. Changes in physical habitat that affect Gila trout density and aquatic macroinvertebrate populations may be causes of variation in condition factor (Turner, 1989).

Mean survival rates for life stages of Gila trout range from 0.128 to 0.497 (Table 3; Brown et al., 2001). Survival rate is defined as the proportion of individuals of age x that survive to age $x + 1$ (Ricklefs, 1990:296-297).

Table 3. Life-stage specific survival rates for Gila trout (from Brown et al., 2001).

Life Stage	Total Length	Survival Rate (mean ± one standard deviation)
Juvenile	<100 mm (<4 in)	0.497 ± 0.445
Subadult	100 to 150 mm (4 to 6 in)	0.128 ± 0.063
Adult	>150 mm (>6 in)	0.430 ± 0.068

On the average, for every 100 eggs that hatch about half will survive to the juvenile life stage. Of those 49 or 50 fish, only about six will survive to the subadult stage and of those six subadults, only two will survive to the adult life stage. Most adult Gila trout live to about age V (Turner, 1986), with a maximum age of IX reported by Nankervis (1988). Thus, the majority of adult female Gila trout only spawn twice before dying and most adult males only spawn three or four times before dying.

Diseases and Pathogens

The carrier of bacterial kidney disease (BKD) is known to occur in trout in the upper West Fork drainage. The carrier, a gram-positive bacterium (*Renibacterium salmoninarum*), occurs in very low amounts in brown trout populations in the upper West Fork Gila River drainage and in the Whiskey Creek population of Gila trout. The bacterium was also detected in rainbow *x* Gila trout hybrid populations in Iron Creek, McKenna Creek, and White Creek. Although the carrier bacterium is present, there were no signs of BKD in any trout population (J. Landye, U.S. Fish and Wildlife Service, pers. comm.). Trout populations in the Mogollon Creek drainage, McKnight Creek, Sheep Corral Canyon, and Spruce Creek all tested negative for BKD.

Whirling disease is caused by the metazoan parasite *Myxobolus cerebralis*. The disease has proved to be a serious problem in hatchery and wild populations of rainbow trout throughout the western United States. There have been no documented cases of whirling disease in the Gila River drainage in New Mexico. All wild and hatchery populations of Gila trout tested negative for whirling disease (J. Landye, U.S. Fish and Wildlife Service, pers. comm.).

Food Habits, Dispersal, and Movement

Gila trout is generally insectivorous. However, the species coevolved with several other fishes and there is some evidence of piscivory in Gila trout. Regan (1964) reported that adult dipterans, trichopteran larvae, ephemeropteran nymphs, and aquatic coleopterans were the most abundant food items in stomachs of Gila trout in Main Diamond Creek. There was little variation in food habits over the range of size classes sampled (47 to 168 [1.8 to 6.6 in] mm total length). These taxa were also predominant in stomach contents of other trout species in the Gila River drainage, indicating the potential for interspecific competition. Hanson (1971) noted that Gila trout established a feeding hierarchy in pools during a low flow period in Main Diamond Creek. Larger fish aggressively guarded their feeding stations and chased away smaller fish.

Van Eimeren (1988) compared food habits of Gila trout and speckled dace in Little Creek and found no significant overlap in diet despite the fact that the two species were found in general proximity. Large Gila trout occasionally consumed speckled dace and may also cannabalize smaller Gila trout (Van Eimeren, 1988; Propst and Stefferud, 1997). Gila trout diet shifted on a seasonal basis as the relative abundance of various prey taxa changed. In February, dipteran larvae (primarily Simuliidae) were very abundant in the stream and were the principal prey of Gila trout. By May, the principal prey shifted to ephemeropteran nymphs (primarily *Paraleptophlebia sp.*) that were present at densities of 177,411/m^2 (16,488/ft^2). No single prey taxon dominated the diet of Gila trout in June. In October, Gila trout shifted to consuming primarily terrestrial insects and benthic *Helicopsyche*. Gila trout fed mainly between the hours of 0900 and 1300, while speckled dace fed primarily between the hours of 2100 and 1300. As in Regan's (1964) study, there was a large overlap in food habits throughout all size classes of Gila trout.

Adult Gila trout are typically quite sedentary and movement is influenced by population density and territoriality (Rinne, 1982). However, individual fish may move considerable distances (i.e., over 1.5 km [0.9 mi]). Gila trout showed a tendency to move upstream in South Diamond Creek, possibly to perennial reaches with suitable pool habitat in response to low summer discharge. Gila trout movement was predominately in a downstream direction in Main Diamond and McKnight creeks. Most of these fish were one or two year-old Gila trout (Rinne, 1982). High density of log structures in Main Diamond Creek appeared to reduce mobility of Gila trout in that stream.

Data collected from White Creek in 1999 and 2000 indicate that dispersal by Gila trout is slow, even when there are no physical barriers to movement (D.L. Propst, New Mexico Department of Game and Fish, pers. comm.). The Lookout Complex fire in 1996 burned much of the White Creek watershed upstream to near Halfmoon Park. During sampling in 1999, Gila trout was found to be absent from all portions of the stream except from about Halfmoon Park upstream. In 2000, the downstream limit of Gila trout was only about 0.5 km (0.3 mi) downstream from Halfmoon Park. Fire-affected reaches of the stream below Halfmoon Park had recovered and were suitable for Gila trout in 2000. These observations indicate that downstream dispersal of Gila trout is limited.

Population Dynamics

Regulation of population size and dynamics of populations of Gila trout are not well understood. Inferences about factors that control population size have been made from analysis of time-series data (Turner and McHenry, 1985; Turner, 1989; Propst and Stefferud, 1997). Density-independent factors, namely hydrologic variability, appear to be most important in regulating population size of Gila trout in many of the streams occupied by the species (e.g., McHenry, 1986; Turner, 1989; Brown et al., 2001). However, density-dependent regulation in the form of competition for space (i.e., territoriality) was suggested as a factor contributing to controlling population size in Main Diamond Creek before that population was extirpated by a stand-replacing forest fire in 1989 (Nankervis, 1988).

The changes in density of Gila trout in McKnight Creek since its establishment provide an example of a population that appears to be regulated primarily by the hydrologic regime, which acts as a major influence on mortality rate. In November 1970, 307 Gila trout were transplanted from Main Diamond Creek to McKnight Creek. The population declined to about 20 fish in 1971, concurrent with a period of low total annual stream discharge (Figure 4A, water years 1969 to 1971). An additional 110 Gila trout were translocated from Main Diamond Creek to McKnight Creek in April 1972 and the population size increased substantially from 1974 to 1976 (Mello and Turner, 1980). The population remained relatively stable from 1977 to 1984 (Turner and McHenry, 1985:47). Flood flows occurred in December 1984 that dramatically reduced the number of age I fish (Turner, 1989:10; Figure 5A). The population of Gila trout then expanded and stabilized following the 1984 flood. Flooding occurred again in August 1988. The 1988 year class was eliminated and the abundance of all other size classes was reduced (Turner, 1989:11; Figure 5A). The population recovered from the 1988 flood impacts by 1992 (Propst and Stefferud, 1997; Figure 5B). The relatively high, consistent flows in 1993 (Figure 4B) resulted in a strong year class and an increase in age I Gila trout in 1994 (Figure 5B).

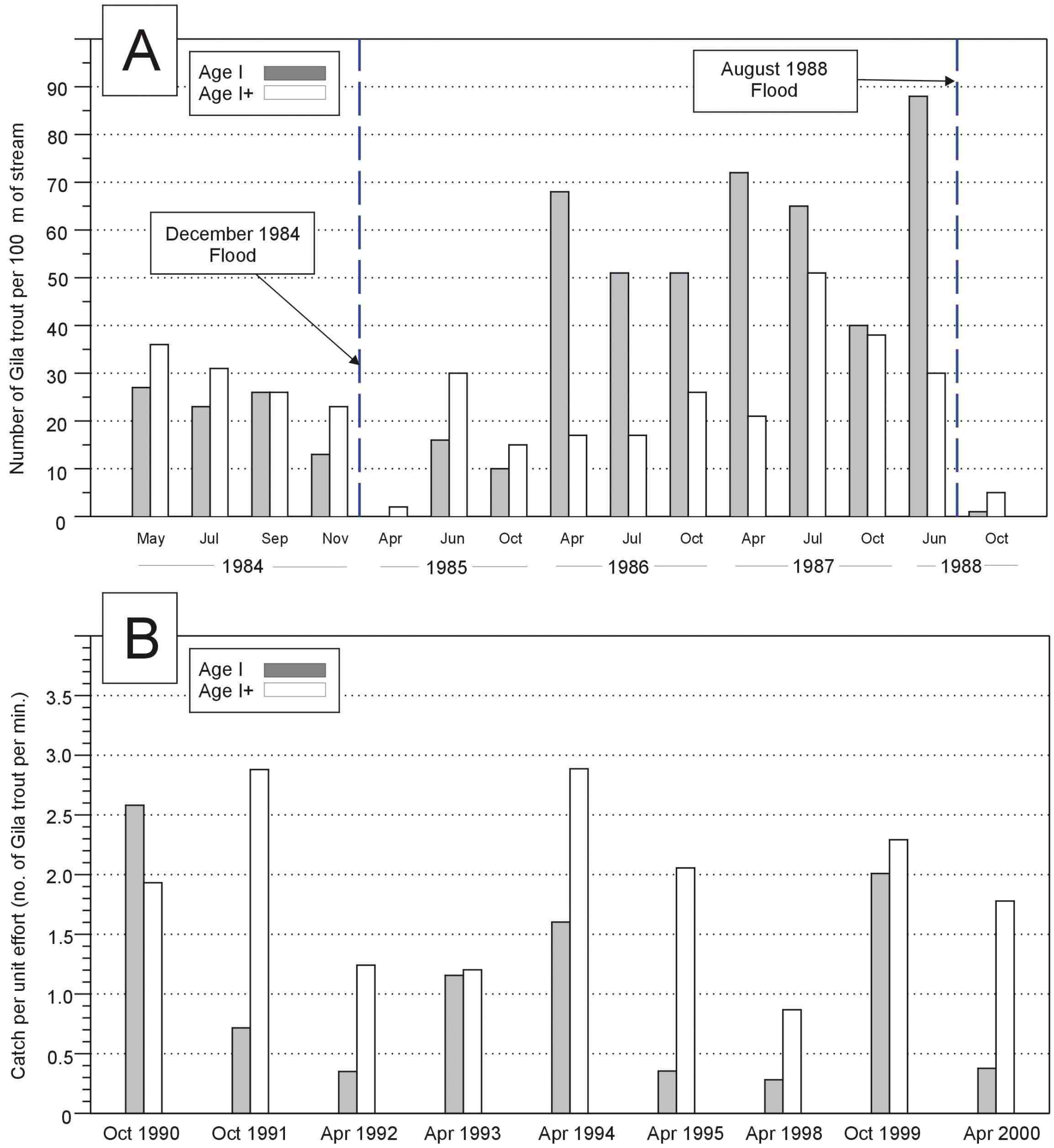
Population Persistence and Viability

Fragmentation of the historical distribution of Gila trout has resulted in several populations confined to small, isolated habitats. These remnant populations characteristically have high densities during relatively stable flow periods (Platts and McHenry, 1988). The overall importance of environmental factors, specifically quantity and variability of stream discharge, in determining persistence of Gila trout populations is evidenced by the effects of fire, flood, and low flow on population size and density of this species. The elimination of the Gila trout population in Main Diamond Creek and extreme reduction of population size in South Diamond Creek following the Divide Fire and subsequent flooding provide a vivid example. Several investigators have indicated the importance of stream discharge in the population dynamics of Gila trout (Regan, 1964; Mello and Turner, 1980; McHenry, 1986; Turner, 1989; Propst and Stefferud, 1997).

Catastrophic events have a much larger influence on the viability of Gila trout populations than do population size, fecundity, or population structure (Brown et al., 2001). High-intensity fires, mainly in the ponderosa pine forest type, have resulted in the extirpation of several populations of Gila trout (Propst et al., 1992). Such stand replacing, high-intensity crown fires in the ponderosa pine forest type were nonexistent before European settlement of the American Southwest (Swetnam, 1990). Reduction of herbaceous vegetation through widespread, intensive livestock grazing since ca. 1900, coupled with decades of fire suppression resulted in radical changes in forest stand structure and fuel loading (Covington and Moore, 1994) Extirpation of fishes from streams following intense forest fires has been documented in other locations in the Southwest and elsewhere in the United States (Hanson, 1971; Novak, 1988; Rinne, 1996; Rieman and Clayton, 1997).

The risk of extinction of Gila trout was also found to be closely related to the number of extant populations. Increasing the number of populations by 11 significantly reduced the probability of extinction from 36% to 12%. The Spruce Creek lineage, which represents the native San Francisco River trout, is at higher risk of extinction than the Gila River lineages due to the small number of populations. Increasing the number of populations in the San Francisco River basin by six reduces the risk of extinction from 81% to 44%. The population viability analysis conducted by Brown et al. (2001) was based on the number of extant populations in 1997 and thus may overestimate risk compared to existing conditions.

Figure 5. Population density of age I and age I+ of Gila trout in McKnight Creek, 1984 through 1988 (A, data from Turner, 1989:10-11),1990 through 1995 (B, data from Propst and Stefferud, 1997), and 1998 through 2000 (B, D.L. Propst, New Mexico Department of Game and Fish, pers. comm.).



Spatial factors have a large influence on population persistence. Habitat complexity and diversity on a spatial scale play an important role in the persistence of salmonid populations subject to catastrophic disturbances such as large, intense forest fires (Rieman and Clayton, 1997). Refuge areas from which fish can disperse into and recolonize depopulated reaches are a critical factor in determining the resilience of a population following a catastrophic event. Such refugia are provided when an entire drainage network, consisting of well-dispersed, perennial mainstem and tributary habitats, is inhabited by the population. Propst and Stefferud (1997) found a positive correlation between density of Gila trout and drainage density, which reinforces the importance of spatial habitat complexity on persistence of populations.

Although Brown et al. (2001) found persistence of Gila trout populations to be relatively insensitive to population size, other studies have indicated that small populations (i.e., less than 2,500 individuals, yielding an effective population size [N_e] of less than 500) are subject to increased risk of extinction (Fritz, 1979; Franklin, 1980; Stacey and Taper, 1992; Allendorf et al., 1997). For inland cutthroat trout, Hilderbrand and Kershner (2000) calculated that at least 8.3 km (5.2 mi) of stream length was required to support a population of 2,500 in streams with high abundance (0.3 trout/m [98.4 trout/100 ft]) and no losses. In situations where trout occurred at low abundance (0.1 trout/m [32.8 trout/100 ft]), at least 25 km (15.5 mi) of stream was required to maintain a population size of 2,500. Hilderbrand and Kershner (2000) concluded that restoration of native trouts to small, isolated segments of headwater streams may result in insufficient space to maintain a population that will persist over the long term. A watershed-level approach with first attention to protection of populations inhabiting long, connected stream reaches was advocated. Within the range of Gila trout, continuous stream segments over 8.3 km (5.2 mi) in length, which provide suitable habitat for salmonids, are rare. Gila trout apparently have persisted in small, isolated stream segments above natural barriers for long periods of time. The resilience of populations following dramatic reductions in population size is a notable characteristic of the population dynamics of the species (Propst and Stefferud, 1997). However, repatriation of the species to connected drainage networks (i.e., a watershed-level approach) would provide spatial diversity and increase population sizes, which in turn would reduce the probability of extinction over the long-term.

MANAGEMENT CHALLENGES

This section describes management challenges and resource conflicts that are known or believed to be responsible for the imperiled status of the Gila trout and that must be addressed for successful recovery. Also, actions that may affect recovery and long term survival of Gila trout are discussed. Activities that may be precluded or reduced by recovery of Gila trout are described.

Fisheries Management

Stocking and naturalization of nonnative trouts within the range of Gila trout and ensuing hybridization, predation, and competition are major causes for the imperiled status of the species (Miller, 1950; Behnke and Zarn, 1976; Sublette et al., 1990; Propst et al., 1992; Turner, 1996). Uncontrolled angling depleted some populations of Gila trout, which in turn encouraged stocking of hatchery raised, nonnative species (Miller, 1950; Propst, 1994). The New Mexico Department of Game and Fish ceased stocking rainbow trout into stream reaches known to support Gila trout beginning around the late 1930's (Miller, 1950). However, stocking of rainbow trout was maintained throughout other portions of the upper Gila River drainage. Rainbow trout and brown trout have become naturalized and are widespread within the historical range of Gila trout. Rainbow trout continue to be stocked in the West Fork Gila River as far upstream as the Gila Cliff Dwellings National Monument (Propst et al., 1998).

A vital component of recovery and long-term survival of Gila trout is removal of nonnative trouts, including Gila *x* rainbow hybrids, from within and adjacent to recovery areas for the species. Stream renovation to remove nonnative trout would result in short-term removal of relatively small reaches of stream from the total mileage of fishable waters in the Gila and San Francisco river drainages. However, restoration of Gila trout populations throughout the historical range of the species would return designated stream reaches to regulated angling use. Stocking of nonnative fish may be precluded in designated areas, as would unregulated harvest of Gila trout.

Forest Management

Forest management includes activities that directly or indirectly affect species composition, density, and vertical structure of vegetation. Changes in these forest variables may affect watershed characteristics such as infiltration, runoff, and erosion and stream habitat characteristics such as sediment transport, nutrient cycling, physical habitat features, and water temperature. Forest management includes silvicultural treatments (e.g., timber harvest, thinning, prescribed burning) and wildfire control.

Although much of the habitat of Gila trout is within designated wilderness where timber harvest is not allowed, historical logging activities likely caused major changes in watershed characteristics and stream morphology. Rixon (1905:15-17) reported the occurrence of small timber mills in numerous canyons of the upper Gila River drainage. Early logging efforts were concentrated along canyon bottoms, often with perennial streams. Tree removal along perennial streams within the historical range of Gila trout likely altered water temperature regimes, sediment loading, bank stability, availability of large woody debris, and other important habitat elements. Fire suppression and altered fire regimes resulted in forest characteristics that differed markedly from pre-settlement conditions, such as increased tree density, reduced average tree diameter, and conifer encroachment in montane grasslands (Cooper, 1960). Corresponding changes in watershed characteristics included increased magnitude and shorter duration of peak flows caused by reduced infiltration and increased runoff, higher sediment loading, cessation of flow from springs and seeps, and lower base flows (Rieman and Clayton, 1997; Gresswell, 1999). Changes in channel morphology associated with altered hydrograph and increased sediment loading include channel incision, headcutting, channel widening, and avulsion. Channel instability brought on by changes in watershed characteristics may persist for decades or centuries (Medina and Martin, 1988; Swanston, 1991).

While restoration of natural forest processes may be beneficial to Gila trout in the long term, short term effects on the ability of individual populations to withstand management actions such as prescribed burning must be carefully considered.

Grazing Management

Poorly managed livestock grazing can degrade watershed condition, stream habitat and riparian environments, resulting in decreased production of salmonids (Platts, 1991; Fleischner, 1994). Historically, widespread, uncontrolled livestock grazing likely contributed to habitat modifications cited by Miller (1950) as a cause for decline of Gila trout. The historical occurrence of intensive grazing and resulting effects on the land are indicated in published reports dating back to the early 1900s (Rixon, 1905; Rich, 1911; Duce, 1918; Leopold, 1921; Leopold, 1924). For example, Rixon (1905:14-15) noted that "In T. 9 S., R. 15 W., a large area, which was entirely given up to sheep, has been overstocked, with the result that about half the township is a barren desert, not a blade of grass being seen and even the roots being entirely destroyed" and "All the country tributary to the East Fork of Gila River is covered with a fine growth of grass, as is the west slope of the Black Mountains, but the remainder of the reserve is carrying too many cattle. If the herds are not reduced for a sufficient time to allow restocking with grass the area will be ruined as grazing land." The reserve indicated by Rixon is the present-day Gila National Forest. The historical effects of intensive, uncontrolled grazing likely affected habitat suitability and thus distribution of Gila trout. Some of these effects, such as drying of perennial springs, channel entrenchment, formation of gullies and headcuts, and lowering of shallow groundwater levels, may persist to the present time.

Seven of the 14 streams occupied by Gila trout as of January 2001 are within Forest Service grazing allotments. Main Diamond Creek and the adjacent riparian zone, located in the South Fork Allotment, are excluded from grazing. However, there have been instances of trespass livestock in the Diamond Pasture of the South Fork Allotment, which includes Main Diamond Creek. The Forest Service is implementing a fencing project along Turkey Run to prevent livestock trespass into Diamond Creek (A. Telles, Gila National Forest, pers. comm.). South Diamond Creek and Black Canyon are within the Diamond Bar Allotment, where grazing has been suspended. Field observations in May 1996 indicated that fish habitat in Black Canyon was impaired by livestock grazing (Gila Trout and Chihuahua Chub Recovery Team, 1997:1). However, subsequent removal of livestock has resulted in marked improvements in condition of riparian and aquatic habitat (D. L. Propst, New Mexico Department of Game and Fish, pers. comm.). Sheep Corral Canyon is within the Cow Creek and Sapillo allotments. Cattle may gain access to the canyon bottom at several locations. Mello and Turner (1980:29) reported the removal of almost all herbaceous vegetation, seedlings, and saplings of woody species in areas of Sheep Corral Canyon that were grazed. McKnight Creek is within the

Powderhorn Allotment, which was leased by The Nature Conservancy in January 2000. Limited cattle grazing may occur on portions of the Powderhorn Allotment in the future, but livestock will continue to be excluded from McKnight Creek (P. McCarthy, The Nature Conservancy, pers. comm.). Mello and Turner (1980:34) reported that recruitment of riparian vegetation was virtually absent due to livestock grazing prior to removal of cattle from the stream bottom. Dude Creek is within the East Verde Pasture of the Cross V Allotment on the Tonto National Forest. Livestock grazing in Dude Creek is limited to short periods annually and currently is not causing degradation of riparian or aquatic habitat. Raspberry Creek is within the Strayhorse and Raspberry allotments of the Apache-Sitgreaves National Forest. Although livestock grazing will continue, the stream is believed to be relatively stable with no signs of erosion or deposition (Stefferud and Young, 1998).

Grazing occurs on streams within the historical range of Gila trout that are currently not inhabited by the species. Renovation and repatriation of Gila trout in such streams may be necessary to meet delisting criteria and ensure long-term survival of the species. Restrictions on grazing in riparian habitats and watersheds of restoration streams may be required to maintain habitat quality and ensure persistence of restored populations. For example, unsupervised horse grazing in Little Creek caused bank instability, extensive browsing of woody riparian vegetation, and sediment input into the stream, which resulted in degraded fish habitat (Gila Trout and Chihuahua Chub Recovery Team, 1993).

REASONS FOR LISTING

This section provides an overview of the decline of Gila trout and the threats facing the species. Threats were identified from published information, including the summary of factors affecting the species published in the Federal Register (U.S. Fish and Wildlife Service, 1987). Threats are described in as much detail as possible. However, lack of quantitative data limits the degree of specificity in the following discussion. Five main threats that have and continue to contribute to the imperiled status of Gila trout have been identified.

Present or Threatened Destruction, Modification, or Curtailment of Habitat or Range

Changes in Habitat Suitability

Miller (1950) documented changes in suitability of habitats for trout in the upper Gila River drainage. In 1898, Gila trout was found in the upper Gila River drainage in New Mexico from the headwaters downstream to the Mogollon Creek confluence. By 1915, the downstream limit in the Gila River had receded upstream to Sapillo Creek. By 1950, water temperature in the Gila River at Sapillo Creek was considered too warm to support any trout species. The causes of habitat degradation were not reported. However, extensive logging and grazing throughout the upper Gila River drainage likely resulted in changes in habitat characteristics such as timing and duration of peak flows, length of perennially-flowing stream channel, base flow discharge, water temperature, and sediment loading (Rixon, 1905; Rich, 1911; Duce, 1918; Leopold, 1921; Leopold, 1924). Also, concentration of early logging impacts along stream bottoms (Rixon, 1905) may have resulted in long-term reduction of the availability of large woody debris in the stream channel, which has been identified as an important component of habitat of Gila trout (Stefferud, 1994).

Catastrophic Forest Fire

High-severity forest fires have caused the extirpation of three populations of Gila trout. The population in Main Diamond Creek was lost in 1989, the population in Burnt Canyon and South Diamond Creek was lost to fire in 1995, and the population in Trail Canyon was extirpated in 1996 (Propst et al., 1992; Brown et al., 2001). Severe forest fires capable of extirpating or decimating fish populations are a relatively recent phenomena, resulting from the cumulative effects of historical or ongoing overgrazing by domestic livestock and fire suppression (Madany and West, 1983; Savage and Swetnam, 1990; Swetnam, 1990; Touchan et al., 1995; Swetnam and Baisan, 1996; Gresswell, 1999).

Overutilization for Commercial, Recreational, Scientific, or Educational Purposes

Uncontrolled Angling

Historically, unregulated harvest of Gila trout likely contributed to the dramatically diminished distribution of the species by the 1960s (Rixon, 1905:50; Propst, 1994). Streams depleted of native trout were then stocked with hatchery-raised, nonnative species to support recreational fishing. By the time regulations were implemented to limit the harvest of fish, the range of Gila trout had been reduced to several isolated headwater streams. Mortality of Gila trout from illegal angling may pose a major threat to some populations.

Disease or Predation

Predation From and Competition With Brown Trout

Brown trout, a nonnative salmonid introduced to the U.S. from Europe, are naturalized throughout the historical range of Gila trout. Brown trout are highly piscivorous and may severely depress populations of Gila trout (Mello and Turner, 1980:27; U.S. Fish and Wildlife Service, 1987).

Disease

The carrier of Bacterial Kidney Disease (BKD), the gram-positive bacterium *Renibacterium salmoninarum*, occurs in very low amounts trout populations in the upper West Fork Gila River, including the Whiskey Creek population of Gila trout (J. Landye, U.S. Fish and Wildlife Service, pers. comm.). Although the carrier is present, there is no evidence of the disease in any population. Whirling disease is not present in any wild or hatchery population of Gila trout.

Inadequacy of Existing Regulatory Mechanisms

Prior to federal listing in 1967, Gila trout had no legal protection. Federal listing provided protection from take. Designation by the State of New Mexico of Gila trout as an endangered species in 1975 prohibited take of the species without a scientific collecting permit.

Other Natural or Man-Made Factors Affecting Its Continued Existence

Introgressive Hybridization with Rainbow Trout

Hybridization with rainbow trout is a major cause for decline and continued imperilment of Gila trout (Miller, 1950; Behnke and Zarn, 1976; David, 1976). Stocking of rainbow trout within the historical range of Gila trout began in 1907 (Miller, 1950:26). Although current stocking of rainbow trout is conducted only in stream segments that are not inhabited by Gila trout, rainbow trout have become naturalized throughout the range of Gila trout. Hybridization remains a prominent threat to Gila trout, as evidenced by loss of previously presumed pure populations (Iron Creek and McKenna Creek) and the detection of recent introgression of rainbow trout genes in the Mogollon Creek population (Leary and Allendorf, 1998). Hybridization is a threat to Gila trout because it results in erosion and loss of the unique genetic identity of the species, which represents its evolutionary history and local adaptation to the environments it inhabits.

CONSERVATION MEASURES

The history of actions from the early 20th century up to the mid-1990s to conserve Gila trout have been recounted by Turner (1986), Propst et al. (1992), Propst (1994), and Turner (1996). The following discussion of conservation measures was adapted from these accounts and other sources.

Early 20th Century through 1960

Initial efforts to conserve Gila trout consisted of attempts by the New Mexico Department of Game and Fish to propagate the species in the early 1920s, when Gila trout was locally recognized as 'mountain trout' or 'speckled trout'. Propagation activities took place at Jenks Cabin Fish Hatchery, starting in 1923, and the Glenwood State Fish Hatchery, beginning in 1937. These Gila trout culture programs were discontinued at the Jenks Cabin and Glenwood hatcheries in 1935 and 1947, respectively, due to low production. After the hatchery programs were abandoned, the New Mexico Department of Game and Fish implemented a policy of not stocking nonnative trout into the streams that were known to be inhabited by Gila trout. In the 1930s, the Civilian Conservation Corps constructed log stream improvement structures in many streams on the Gila National Forest. Scientific investigation of Gila trout originally came at the request of Elliot S. Barker, State Game Warden of New Mexico, and led to the description of the species from specimens taken at Glenwood Hatchery and Main Diamond Creek in 1939 (Miller, 1950). The New Mexico Department of Game and Fish closed Main Diamond Creek to fishing in 1958 (Hanson, 1971).

1960 through 1979

Summary

A study of the ecology of Gila trout in Main Diamond Creek was sponsored by the New Mexico Department of Game and Fish in the early 1960s (Regan, 1966). Another study was completed in 1971, which included a study of the Main Diamond Creek population and identification of Gila trout populations in South Diamond, Spruce, and McKenna creeks (Hanson, 1971). The first comprehensive taxonomic analysis of Gila trout was completed in 1970s (David, 1976), as was a cytotaxonomic study (Beamish and Miller, 1977). Methods for population estimation and habitat evaluation were tested in the late 1970s (Rinne, 1978). The first comprehensive assessment of the distribution of Gila trout was completed in the late 1970s (Mello and Turner, 1980). Replicate populations of the Main Diamond Creek lineage were established in McKnight Creek, Sheep Corral Canyon, and Gap Creek by direct transfer of fish from wild populations. The original recovery plan for Gila trout was completed in 1979.

Chronological Account

Gila trout was listed as endangered in the U.S. Fish and Wildlife Service "Red Book" in 1966. The species was listed as endangered in 1967 under the federal Endangered Species Preservation Act of 1966 (U.S. Fish and Wildlife Service, 1967). A study conducted during 1969 and 1970 resulted in selection of McKnight Creek in the Mimbres River drainage as a replication site for the Main Diamond Creek population of Gila trout (Hanson, 1971). After construction of a barrier and elimination of the native Rio Grande sucker (*Catostomus plebeius*) with rotenone, 307 Gila trout were transplanted from Main Diamond Creek into McKnight Creek in November 1970. A management plan for Gila trout was developed by the Gila National Forest and New Mexico Department of Game and Fish in 1972 (Bickle, 1973). On 27 April 1972, 110 Gila trout from Main Diamond Creek were translocated into McKnight Creek to supplement the population. Also in 1972, 89 Gila trout from Main Diamond Creek were transplanted into Sheep Corral Canyon in an attempt to establish a new population in that stream (Turner, 1989). Sheep Corral Canyon above the waterfall was devoid of fish prior to the transplant. The Endangered Species Act of 1973 provided protection to all species of wildlife that had been designated under the Endangered Species Preservation Act of 1966, which included Gila trout (U.S. Fish and Wildlife Service, 1975). In 1974, 65 Gila trout from Main Diamond Creek were translocated into Gap Creek, a tributary of the Verde River on the Prescott National Forest in Arizona (Minckley and Brooks, 1985; Warnecke, 1987). Stream surveys were conducted in 1974 and 1976 that established the distribution and status of Gila trout (David, 1976; Mello and Turner, 1980).

In 1979, the Gila Trout Recovery Plan was approved by U.S. Fish and Wildlife Service with the main objective being "To improve the status of Gila trout to the point that its survival is secured and viable populations of all morphotypes are maintained in the wild" (U.S. Fish and Wildlife Service, 1979). An environmental assessment for Gila trout recovery projects on the Gila National Forest was approved in 1979 that authorized the stabilization and replication of indigenous populations of Gila trout involving both artificial barrier construction and piscicide application in streams within the Gila Wilderness (U.S. Forest Service, 1979).

1980 through 1989

Summary

Substantial progress was made in the 1980s in renovating streams, constructing barriers, and establishing new populations of Gila trout. Barriers were constructed on Iron and Little creeks. Populations of Gila trout were established in Little Creek, Big Dry Creek, upper Mogollon Creek, and Trail Canyon by direct transfer of fish from wild populations and hatchery-reared stock. The use of hatchery-reared stock began in 1989. The population in Iron Creek was extended into downstream reaches. Monitoring of extant populations of Gila trout was conducted (Turner and McHenry, 1985; Turner, 1989) and numerous studies on the systematics, biology, habitat, and ecology of Gila trout were completed (Rinne, 1980; Lee and Rinne, 1980; Rinne, 1981a; Rinne, 1981b; Rinne, 1982; Mpoame and Rinne, 1984; Loudenslager et al., 1986; McHenry, 1986; Pittenger, 1986; Medina and Martin, 1988; Nankervis, 1988; Van Eimeren, 1988). The recovery plan was revised in 1984. A comprehensive study of genetics of Gila trout was initiated at the end of the decade. A catastrophic forest fire in the watershed of Main Diamond Creek in 1989 extirpated that population of Gila trout and prompted reevaluation of downlisting criteria and recovery actions.

Chronological Account

In 1981, a concrete and native rock barrier was constructed on Iron Creek about 2.9 km (1.8 mi) downstream from an intermittent stretch of the stream. Brown trout density was reduced with Antimycin A between the barrier and the intermittent reach after Gila trout had been removed from the area by electrofishing and placed in holding pens isolated from the toxicant. Gila trout were prematurely released into the renovated area and suffered high mortality (Coman, 1981). In 1984, 105 Gila trout were moved from the upper reach of Iron Creek downstream to the renovated area (Turner, 1989). Brown trout were removed from the renovated reach in 1985 and 12 age II brown trout were removed in 1988.

Little Creek was selected as a site to replicate the population of Gila trout in McKenna Creek. In 1982, a concrete and native rock barrier was constructed on Little Creek and approximately 9 km (5.6 mi) of stream above the barrier were treated to remove nonnative trout. Desert sucker (*Catostomus clarki*) was also eliminated; however, speckled dace (*Rhinichthys osculus*) survived the treatment. In December 1982, 100 Gila trout were successfully transported from McKenna Creek to Little Creek.

The Gila Trout Recovery Plan was revised in 1984 with the same objective as the original plan. Downlisting criteria in the plan stated that "The species could be considered for downlisting from its present endangered status to a threatened status when survival of the five original ancestral populations is secured and when all morphotypes are successfully replicated or their status otherwise appreciably improved" (U.S. Fish and Wildlife Service, 1984).

The Spruce Creek population was replicated in Big Dry Creek in 1985. A 1.9 km (1.2 mi) reach of Big Dry Creek above a 20 m (66 ft) high waterfall was treated with Antimycin A in 1984. The first treatment did not remove all nonnative trout, so another treatment was applied in 1985. In October 1985, 97 Gila trout were translocated from Spruce Creek to the renovated reach of Big Dry Creek.

Upper Mogollon Creek and Trail Canyon were selected as sites for replicating the Gila trout population in South Diamond Creek. Trail Canyon was treated with Antimycin A in October 1986 to eradicate nonnative trout. The stream was treated again in July 1987 to remove remaining nonnative trout. In September 1987, Trail Canyon was found to be barren and 305 Gila trout were transported by helicopter from South Diamond Creek and stocked into Trial Canyon. In October 1988, fish from South Diamond were used to supplement the Trail Canyon population (Propst et al., 1992). Mogollon Creek, from its source to the confluence with Trail Canyon, was initially treated with Antimycin A to remove nonnative trout in July 1987. Nonnative trout survived the initial treatment of upper Mogollon Creek and the stream was treated again in July 1988. At the same time Woodrow Canyon, a renovated tributary of upper Mogollon Creek, was stocked with Gila trout from South Diamond Creek. In April

1989, Gila trout brood stock were obtained from South Diamond Creek and taken to Mescalero National Fish Hatchery, and a third Antimycin A treatment was made. Eradication of nonnative trout in upper Mogollon Creek was confirmed in May 1989 and, in October 1989, the creek was stocked with 100 fingerling Gila trout from Mescalero National Fish Hatchery and 93 Gila trout from Trail Canyon.

In 1987, it appeared that downlisting criteria were rapidly being achieved, so the species was proposed for downlisting from endangered to threatened status (U.S. Fish and Wildlife Service, 1987). In July 1989, a large portion of the 24,762 ha (61,190 ac) Divide Fire burned in the Main Diamond Creek watershed. An emergency evacuation operation during the peak of the fire removed 566 Gila trout from the stream to Mescalero National Fish Hatchery. Main Diamond Creek was sampled extensively in October 1989 and again in May 1990. The results of these surveys confirmed that the population of Gila trout in Main Diamond Creek had been extirpated. In October 1989, 200 of the evacuated Gila trout from Main Diamond Creek were stocked into McKnight Creek. The Divide Fire and loss of Gila trout prompted postponement of the downlisting proposal.

A genetics study, including analysis of mitochondrial and nuclear DNA of all known Gila trout populations, suspected Gila trout populations, and related species was initiated in January 1988. Tissue samples for the study were collected in 1988 and 1989.

1990 through 2000

Summary

The 1990s saw continued expansion of the range of Gila trout. A population of Gila trout was discovered in Whiskey Creek, a small tributary to the upper West Fork Gila River. The Iron Creek population was replicated in Sacaton Creek. Main Diamond Creek lineage Gila trout were translocated from McKnight Creek back into Main Diamond Creek, following recovery of that stream from fire impacts. Main Diamond lineage Gila trout were also stocked in lower Little Creek. Upper Little Creek was stocked with Gila trout from Whiskey Creek to establish a replicate of that population. A second replicate population of the Spruce Creek lineage was established in Dude Creek, Arizona. However, forest fires continued to plague recovery efforts. The South Diamond Creek and Burnt Canyon populations were extirpated by forest fire in 1995. A fire in the Spruce Creek drainage prompted emergency evacuation of several hundred fish to ensure survival of that lineage.

The Gila Trout Recovery Plan was revised in 1993 to incorporate new information about the ecology of the species and recovery methods obtained since the 1984 revision. Criteria for downlisting remained essentially the same as in the 1984 revision but were more specific. The 1993 plan specified that downlisting would be considered “when all known indigenous lineages are replicated in the wild” and when Gila trout were “established in a sufficient number of drainages such that no natural or human-caused event may eliminate a lineage.”

Controversy regarding the use of Antimycin A and removing nonnative trout populations stalled recovery efforts from 1994 through 1997. Substantial efforts were made by recovery team members, participating agencies, and team advisors to inform local government staff and concerned public about the use and effects of Antimycin A, the Gila trout recovery program, and stream renovation. These efforts included meetings in Reserve, Silver City, Willow Creek, and Las Cruces, personal contacts, dissemination of fact sheets, publication of an article in *New Mexico Wildlife* (Propst, 1994), and publication of peer-reviewed articles that summarized recovery efforts and conservation status of the species (Propst et al., 1992; Turner, 1996).

Studies on the habitat (Stefferud, 1994) and population dynamics (Propst and Stefferud, 1997) of Gila trout were completed in the 1990s. Considerable information was developed on the molecular genetics of Gila trout (Leary and Allendorf, 1998; Riddle et al., 1998; Nielsen et al., 1998; Leary and Allendorf, 1999; Leary et al., 1999). Most importantly, it was discovered that two of the relict populations had been introgressed with rainbow trout. Introduction of rainbow trout into the McKenna Creek population was first identified by Riddle et al. (1998) using analysis of mitochondrial DNA. Leary and Allendorf (1998) confirmed hybridization with rainbow trout in the McKenna Creek and Iron Creek populations and indicated that one or two introductions of rainbow trout had likely occurred sometime between 1930 and 1950. The proportion of rainbow trout genes in these two introgressed populations is about 10%. The molecular genetics investigations also identified unique genetic material in each of the other relictual populations, reinforcing the need to replicate each lineage.

The Bonner Fire eliminated nonnative trout from Black Canyon in 1995. Inventories conducted in 1996 and 1997 confirmed the absence of nonnative trout and a fish barrier was constructed on the stream. The barrier was constructed with substantial assistance from volunteers. Main Diamond lineage Gila trout were stocked in Black Canyon above the barrier in 1998 and 1999.

Extensive efforts involving field collections throughout the decade resulted in establishing a captive population of Main Diamond Creek lineage Gila trout at Mescalero National Fish Hatchery. Brood stock were transferred to the Mora National Fish Health and Technology Center with the cessation of operations at Mescalero National Fish Hatchery.

Chronological Account

Stream habitat improvements were constructed and willow cuttings were planted in McKnight Creek in 1989 and 1990 by the U.S. Forest Service and New Mexico State University. The Iron Creek population of Gila trout was replicated at Sacaton Creek in May 1990, when 40 fish were stocked into the barren stream. A second stocking of 60 Gila trout from Iron Creek was made into Sacaton Creek in June 1991. Persistence of the brown trout population in Iron Creek, discovery of introgressive hybridization of rainbow trout in the McKenna Creek population, and extirpation of populations caused by catastrophic forest fire, resulted in a reevaluation and withdrawal of the 1987 downlisting proposal in 1991. A previously unknown population of Gila trout was discovered in an unnamed tributary to the West Fork Gila River in 1992. The tributary, informally referred to as Whiskey Creek, is in the upper reaches of the West Fork Gila River.

A fish barrier was improved on Mogollon Creek in July 1993 to prevent upstream movement of brown trout. A reach of White Creek above a waterfall barrier was renovated with three treatments of Antimycin A and 265 Gila trout from Iron Creek were transported to the stream on 21 October 1993.

A second stocking was made in 1995. Evidence of illegal angling was discovered in Iron Creek in October 1993.

In May 1994, recovery team members and advisors to the team convened public meetings in Reserve, Silver City, and at Willow Creek to discuss recovery actions and address local concerns about stream renovation and the use of Antimycin A. Substantial opposition to stream renovations had been building and resulted in the postponement of removing nonnative trout from Mineral and Mogollon creeks. One-hundred and fifty Gila trout were evacuated from Spruce Creek during a forest fire in the upper watersheds of Spruce and Big Dry creeks in June 1994. The fish were transported to Mescalero National Fish Hatchery, where they suffered a high rate of mortality. The wild Spruce Creek and Big Dry Creek populations survived the fire. Monitoring of watershed condition at Main Diamond Creek indicated that the stream had recovered to the point that Gila trout could be repatriated to the stream (Wood and Turner, 1992; Wood and Turner, 1994; Jacobi, *in litt.*). In September 1994, 195 Gila trout were translocated from McKnight Creek to Main Diamond Creek to reestablish a population.

Public meetings on Gila trout recovery activities were convened in Las Cruces, Silver City, and Reserve in March 1995. The purpose of these meetings was to provide information about the recovery program. Recovery team members also met with the Grant County Commission in July and November. The November meeting was also attended by the Gila Rod and Gun Club. Gila trout recovery issues, including removal of nonnative trout and use of Antimycin A, were discussed at these meetings. A forest fire (the Bonner Fire) caused the extirpation of the South Diamond Creek and Burnt Canyon populations of Gila trout in summer 1995. The fire also eliminated nonnative trout from Black Canyon. Another fire in the Mogollon Creek watershed resulted in marked reductions of Gila trout numbers in Corral and Trail canyons. About 430 Gila trout were removed from Trail Canyon and Mogollon Creek during the fire. The fish were transported to Mescalero National Fish Hatchery. Approximately 50 Age 0 Gila trout of Main Diamond lineage, which were raised at Mescalero National Fish Hatchery, were stocked into Main Diamond Creek in September 1995. Another 150 Gila trout were collected from Iron Creek and stocked into White Creek in October 1995.

Mogollon Creek, from Woodrow Canyon downstream to a waterfall, Trail Canyon, and South Fork Mogollon Creek were treated with Antimycin A in August 1996 to remove nonnative trout. Questions regarding the genetic purity of several Gila trout populations were raised in summer 1996. Dr. Robb Leary, Montana State University, was retained to resolve the genetics questions and conduct molecular genetics analyses of tissues taken from all extant populations. Initial results indicated that the Mogollon Creek population, which was established from the South Diamond lineage, had recently been contaminated with rainbow trout.

A memorandum of understanding between the U.S. Forest Service, New Mexico Trout, New Mexico Department of Game and Fish, and the Rio Grande Chapter of Trout Unlimited was executed in early 1997. The memorandum described a framework for cooperative efforts between the signatories to conserve native trouts and their habitats. Progress on the molecular genetics work by Dr. Robb Leary indicated that the South Diamond lineage could be salvaged by conducting paired matings of Mogollon Creek fish. In November 1997, 500 Age 0 Main Diamond lineage Gila trout from Mescalero National Fish Hatchery were stocked into Main Diamond Creek to supplement that population. Two Antimycin A treatments of Mogollon Creek from the headwaters downstream to a waterfall barrier were completed in summer 1997. Prior to the first treatment, 650 Gila trout were removed from Mogollon Creek and taken to Mescalero National Fish Hatchery. These fish and Gila trout from Trail Canyon were used in paired matings to restore the South Diamond lineage. Mogollon Creek was then stocked with about 1,200 Age 0 South Diamond lineage Gila trout from Mescalero National Fish Hatchery in October. Another 500 Age 0 South Diamond lineage fish were stocked from the hatchery into South Diamond Creek in November. Results of the molecular genetics investigations indicated that both the McKenna Creek and Iron Creek populations were introgressed with rainbow trout. Rainbow trout hybridization had occurred to the point that paired matings could not be employed to restore the pure Gila trout lineage of either stream.

A gabion waterfall barrier was constructed in June and July 1998 on Black Canyon, with considerable assistance from volunteers (Propst, 1999). Prior to completion of the barrier, brown and rainbow trout were found to have been recently introduced into the stream. Nonnative salmonids were removed by intensive electrofishing (Brooks and Propst, 1999). In November, 13,000 Age 0 South Diamond lineage Gila trout were stocked into the stream above the barrier. Little Creek was treated with Antimycin A in November 1998 to remove the population of Gila *x* rainbow trout hybrids. A meeting was convened in Silver City on 21 October 1998 with the New Mexico Department of Game and Fish, U.S. Fish and Wildlife Service, U.S. Forest Service, Grant County Commission, Gila Rod and Gun Club, and People for the U.S.A. to discuss the status of Gila trout recovery.

All extant populations of Gila trout, except Whiskey Creek, were sampled in 1999 to assess density and population structure of Gila trout. Little Creek was treated again with Antimycin in 1999 to remove the Gila *x* rainbow trout hybrid population. In late September 1999, 126 Gila trout were collected from Spruce Creek and translocated to Dude Creek in Arizona, to establish a second replicate population of the Spruce lineage. The Dude Creek population was supplemented in early November 1999 with 17 age 0 Gila trout of Spruce Creek lineage. About 20,000 Age 0 Main Diamond lineage Gila trout were stocked into Black Canyon on 20 October 1999.

Main Diamond lineage Gila trout were stocked from Mescalero National Fish Hatchery into lower Little Creek in April and October 2000. Also in April 2000, approximately 30 Gila trout were translocated from Whiskey Creek to upper Little Creek. Another 10 Gila trout were collected from Whiskey Creek and transferred to the Mora National Fish Health and Technology Center. These captive fish were spawned and 13 Gila trout reared from the spawn were stocked into upper Little Creek in October 2000. In May 2000, 22 adult Gila trout were collected from Spruce Creek, spawned, and then translocated to Dude Creek. The fertilized eggs from the spawn were taken to Mescalero National Fish Hatchery. One-hundred and thirteen age 0 fish produced from these fertilized eggs were stocked in late November 2000 into Raspberry Creek, a tributary to Blue River in Arizona. This stocking established the third replicate of the Spruce Creek lineage. Operations at Mescalero National Fish Hatchery were suspended in September 2000 because of flood damage. All Gila trout brood stock held at the facility were transferred to the Mora National Fish Health and Technology Center.

STRATEGY FOR RECOVERY

Gila trout was once widespread in the upper Gila River Basin, but has declined because of hybridization with rainbow trout, predation by and competition with brown trout, and habitat degradation. The current distribution of Gila trout consists of 14 populations in headwater stream habitats. Recovery efforts are intended to ameliorate the five main threats that have and continue to contribute to the imperiled status of the Gila trout. These efforts will restore the species to drainages within its historical range and ensure long-term survival of the species, as represented by each of the four known, non-hybridized genetic lineages.

Recovery of Gila trout will serve to maintain biological diversity and restore a native faunal component of the Gila River drainage in New Mexico and Arizona. Conservation of a species that has evolved and adapted over thousands of years will be accomplished by recovery of Gila trout. Restoration streams for repatriating Gila trout are situated on lands managed by the U.S. Forest Service. Many of the potential restoration streams are located within federal-designated wilderness areas.

Recovery efforts involve four priorities:

1) Repatriate Gila trout to streams and complex drainages within its historical range;

2) Conserve habitat of Gila trout through protection, restoration, and maintenance;

3) Continue to investigate aspects of the biology, ecology, life history, habitat, and genetics of the species that are important for conservation of Gila trout; and

4) Inform the public about the status of recovery actions and issues associated with recovery of Gila trout.

The first priority addresses preventing extinction or irreversible decline by repatriating Gila trout to streams and complex drainages within its historical range. This will be accomplished by using known, non-hybridized lineages to increase population abundance, increase geographic distribution of the species, and restore some measure of population connectivity.

Brown et al. (2001) demonstrated that risk of extinction over a 100-year time frame is highly sensitive to the number of extant populations. Addition of populations substantially reduced the probability of extinction in their model. Therefore, a primary aspect of the recovery strategy that addresses preventing extinction must be establishing additional populations.

Another critical component of extinction risk is effective population size. Small populations with an effective population size (N_e) of less than 500 are subject to increased risk of extinction (Fritz, 1979; Franklin, 1980; Stacey and Taper, 1992; Allendorf et al., 1997). Population size is primarily a function of the amount of available habitat. For example, Hilderbrand and Kershner (2000) calculated that at least 8.3 km (5.2 mi) of stream length was required to support a cutthroat trout effective population size of 500, where trout density was high. Trout streams of such length are uncommon within the geographic range of Gila trout. However, repatriation of the species to complex drainages where several streams are hydrologically connected by suitable habitat can provide sufficient habitat quantity. Gila trout have persisted in small, isolated stream segments above natural barriers for long periods of time. These populations are quite resilient and also contribute to recovery of the species.

Based on the best scientific information available, the most prudent course of action to prevent the extinction or irreversible decline of Gila trout is to increase the number of populations and increase the amount of habitat occupied by the species. Repatriation of Gila trout to entire watersheds where there are several, connected restoration streams most effectively achieves this goal. However, isolated, single streams also contribute to this goal.

Genetic variability in Gila trout must also be preserved and restored, to the extent possible, to ensure persistence of the species. Genetic investigations have indicated that conservation of Gila trout as two recovery units is warranted (Leary and Allendorf, 1998; Riddle et al., 1998). The Gila River Recovery Unit is composed of the Main Diamond, South Diamond, and Whiskey Creek lineages and the San Francisco River Recovery Unit is represented by the Spruce Creek lineage. Determinations of appropriate lineage stock for a given restoration stream will be based on recovery unit and zoogeographic considerations. To the extent possible, recombination of lineages and the two recovery units will be conducted to restore genetic variation in Gila trout. Zoogeographic considerations will serve as the basis for recombining lineages and recovery units. For example, suitable habitats downstream from the confluence of the San Francisco River with the Gila River, such as Eagle Creek or streams in the Pinaleno Mountains, could be potential sites for mixing the San Francisco River and Gila River recovery units (R. David, U.S. Fish and Wildlife Service, pers. comm.).

In 1997, the Iron Creek and McKenna Creek lineages were found to be introgressed with rainbow trout. Hybridization of these two populations occurred prior to 1950 (Allendorf and Leary, 1998). The hybridized populations in McKenna Creek, Iron Creek, and Sacaton Creek (a replicate of Iron Creek) no longer contribute to recovery of Gila trout and will not be further replicated.

Potential restoration streams will be identified, evaluated, and renovated using proven techniques. Hatchery stock will be established and used to produce adequate numbers of fish for recovery actions. Hatchery facilities will also serve as short-term refugia to ensure the security of lineages. Monitoring of populations and habitat will be conducted to measure progress toward recovery.

Following downlisting, limited sport fishing for Gila trout will be permitted in selected waters. Stocking of nonnative trout will be replaced by stocking of Gila trout to maintain sport fisheries. Fishing regulations will be established to ensure that angling pressure does not result in decline of the species. Nonnative trout will continue to be removed from within the range of Gila trout. Following delisting, Arizona and New Mexico will promulgate regulations to manage Gila trout as a sport fish.

Interagency consultation, pursuant to section 7 of the Endangered Species Act, will be conducted to ensure that federally funded, supported, or permitted actions further conservation and recovery of Gila trout. Information needs will be identified and appropriate research will be supported. Materials will be developed to keep the public informed about status of recovery. Public involvement in recovery will be encouraged through volunteer activities.

CROSS-REFERENCE TO OTHER RECOVERY PLANS

Recovery plans have been approved for Mexican spotted owl (*Strix occidentalis lucida*) and Mexican gray wolf (*Canis lupus baileyi*), both of which occur within the range of Gila trout. Recovery plans have also been developed for loach minnow (*Tiaroga cobitis*) and spikedace (*Meda fulgida*), which are typically found downstream from habitats that are suitable for Gila trout. Similarly, southwestern willow flycatcher (*Empidonax traillii extimus*) is not known to occur in habitats suitable for Gila trout, but it is found in riparian areas downstream from suitable trout habitat. There is no approved recovery plan for southwestern willow flycatcher, but a draft is currently under review. Measures recommended to improve and protect habitat of Mexican wolf are consistent with recovery of Gila trout (U.S. Fish and Wildlife Service, 1982:38).

Actions recommended in the recovery plans for loach minnow and spikedace are consistent with and may be furthered by conservation measures recommended for Gila trout. Primarily, measures aimed at restoring habitat of spikedace and loach minnow would benefit Gila trout at the lower limits of its distribution. Similarly, conservation measures for Gila trout that restore natural flows and watershed structure and function would benefit downstream habitats for spikedace and loach minnow. Relevant habitat restoration recommendations in the recovery plans for spikedace and loach minnow include: discouraging detrimental land and water use practices; ensuring perennial flows with natural hydrographs; identifying, obtaining, and protecting important lands and water rights that are available for acquisition; and enhancing or restoring habitat (U.S. Fish and Wildlife Service, 1991a:13-20; U.S. Fish and Wildlife Service, 1991b:12-19). The recovery plans for spikedace and loach minnow also call for constructing fish barriers to prevent upstream movement of nonnative fishes and curtailing transport and introduction of nonnative fish (U.S. Fish and Wildlife Service, 1991a:14; U.S. Fish and Wildlife Service, 1991b:13). These measures are consistent with and would further recovery and conservation of Gila trout.

The recovery plan for Mexican spotted owl contains recommendations for improving and protecting forest health (U.S. Fish and Wildlife Service, 1995:84-98), which would benefit Gila trout by improving watershed conditions and reducing the potential for catastrophic forest fire. The plan also recommends restoration and maintenance of riparian habitats, which is consistent with and would further recovery of Gila trout (U.S. Fish and Wildlife Service, 1995:95-98).

RECOVERY ANALYSIS

OBJECTIVE AND CRITERIA

Downlisting

Downlisting of Gila trout from endangered to threatened status will be considered when: 1) the four known, non-hybridized, indigenous lineages are protected and replicated in the wild in at least 85 km (53 mi) of stream; 2) each known, non-hybridized lineage is replicated in a stream geographically separate from its remnant population such that no natural or human-caused event may eliminate a non-hybridized, indigenous lineage; and 3) an emergency rescue plan to address wildfire-related impacts and discovery of nonnative salmonid invasion in Gila trout streams has been developed and implemented.

The 1993 revision of the Gila trout recovery plan considered the Iron Creek and McKenna Creek populations to be pure lineages of Gila trout. However, molecular genetic analyses completed in 1997 found that both populations were introgressed with rainbow trout (Leary and Allendorf, 1998; Riddle et al., 1998). Furthermore, the analyses indicated that hybridization resulted from one or two introductions of rainbow trout, as evidenced by the fairly low proportion of rainbow trout genes in the population. The analyses also revealed that the introductions had occurred prior to 1950, indicated by the widespread occurrence of rainbow trout genes in both populations. This finding changed the status of the Iron Creek and McKenna Creek populations from presumed pure lineages to hybridized populations. Therefore, the Iron Creek and McKenna Creek populations or any extant replicates of these populations no longer contribute to recovery of Gila trout.

The remaining known, non-hybridized lineages (Main Diamond, South Diamond, Whiskey, and Spruce) have each been replicated in the wild. The spatial separation of existing populations achieves the objective of protecting a lineage from elimination by a single natural or human-caused event. Additionally, effective short-term refugia strategies are in place to quickly rescue and protect specific populations, should they become vulnerable to such events.

Delisting

The molecular genetics work completed in 1997 described substantial differentiation between the Spruce Creek lineage and the three pure upper Gila River drainage lineages (Leary and Allendorf, 1998; Riddle et al., 1998). Examination of historical collection information, phenotypic variation, and genetic data also indicated that the Spruce Creek lineage had differentiated from the upper Gila River drainage lineages (David, 1998). These analyses strongly supported management of Gila trout as two recovery units, representing distinct evolutionary units (Riddle et al., 1998). The Gila River recovery unit consists of three genetically-intact, relict lineages (Main Diamond, South Diamond, and Whiskey). The San Francisco recovery unit consists of one genetically-intact, relict lineage: Spruce Creek.

Delisting of Gila trout will be considered when: 1) at least 20 populations in the Gila River Recovery Unit are established in at least 150 km (93 mi) of stream; 2) at least 15 populations in the San Francisco

River Recovery Unit are established in at least 80 km (50 mi) of stream; and 3) at least four San Francisco-Gila River mixed lineage populations are established in at least 40 km (25 mi) of stream.

Potential restoration streams and streams with existing populations of Gila trout are listed in tables 4 and 5. Potential restoration streams shown in these tables will require further evaluation and some may be dropped from consideration. Also, other potential restoration streams may be identified, which are not shown on the tables. Such streams may also be considered for repatriation of Gila trout.

Individual streams or drainage complexes in the Blue River and San Francisco River drainages will be restored with the Spruce Creek lineage. The Gila Recovery Unit lineages will be restored to drainages in the Upper Gila River. Habitats downstream from the Blue River in Arizona, such as Eagle Creek, East Verde River, Verde River, and Agua Fria River drainages will be restored using lineages from both recovery units.

Recovery streams will be selected so that a single catastrophic event would be unlikely to eliminate a population. To achieve this, a drainage complex approach will be implemented. Drainage basins within the historical range of the species will be assessed. Basins containing hydrologically connected perennial tributaries and main stem streams with suitable trout habitat and natural barriers or feasible artificial barrier sites will be selected as top priority sites for recovery. Restoration streams will be located far enough away from parent populations to add a measure of security in the event of catastrophic events that may extirpate a given population.

A population will be considered established when it is self-sustaining, capable of persisting under the range of variation in habitat conditions that occur in the restoration stream (cf. Propst and Stefferud, 1997), and when the population is protected from immigration of nonnative trout. Naturally-functioning stream habitat is characterized by unregulated stream flow, properly functioning riparian areas (Prichard et al., 1998), watershed condition that produces a natural hydrograph, and the absence of nonnative fishes. Recovery streams should exhibit these conditions or should be under management to restore these conditions. Restoration streams that are subject to livestock grazing will be managed to maintain healthy riparian vegetation and good watershed condition. Adequate riparian and watershed condition will be indicated by rates of infiltration, runoff, upland erosion, bank erosion, and sediment transport and storage that occur in naturally-functioning systems.

Suppression of wildfire will be an appropriate response in streams containing Gila trout. Prescribed fire may be used in selected portions of watersheds with streams inhabited by Gila trout or in restoration streams prior to introduction of Gila trout. The use of prescribed fire in watersheds with streams inhabited by Gila trout will be carefully planned and managed to avoid detrimental effects on populations of Gila trout.

Streams restored to Gila trout will be selectively opened to limited sport fishing following downlisting from endangered to threatened status. Sport-fishing management plans will be developed for these streams to ensure that angling does not jeopardize persistence of the population. Eventually, hatchery-produced Gila trout will be stocked instead of nonnative trout to maintain sport fisheries.

Table 4. List of existing and potential restoration streams for the Gila River Recovery Unit lineages. Streams with existing populations of Gila trout are indicated by 'Y' in the 'Existing' column, while those that may be considered for restoration of Gila trout are indicated by 'N' in the 'Existing' column. Stream lengths are estimates of the amount of suitable habitat at each location. Stream lengths are estimates of the amount of suitable habitat at each location. Sources for stream length estimates were: Gila Trout and Chihuahua Chub Recovery Team, 1999; Gila Trout and Chihuahua Chub Recovery Team, 1997; Johnson, 1999; and Arizona Department of Water Resources, 1994.

MAIN DIAMOND LINEAGE	km	mi	Drainage	County	State	Existing
Main Diamond Creek	6.10	3.79	E. Fork Gila	Sierra	NM	Y
McKnight Creek	8.50	8.50	Mimbres	Grant	NM	Y
Sheep Corral Canyon	1.30	0.81	Gila	Grant	NM	Y
Black Canyon	18.20	11.31	E. Fork Gila	Grant	NM	Y
Upper White Creek	8.80	5.47	W. Fork Gila	Catron	NM	Y
Rain Creek	11.30	7.02	Gila	Grant	NM	N
West Fork Mogollon Creek	10.00	6.21	Gila	Grant	NM	N
Cub-Langstroth-Rawmeat Complex	13.60	8.45	W. Fork Gila	Catron	NM	N
Total Stream Length	**77.80**	**51.56**				
SOUTH DIAMOND LINEAGE	**km**	**mi**	**Drainage**	**County**	**State**	**Existing**
South Diamond Creek	6.70	4.16	E. Fork Gila	Sierra	NM	Y
Mogollon Creek Complex	28.80	17.90	Gila	Catron, Grant	NM	Y
S. Fork Mogollon Creek	11.50	7.15	Gila	Grant	NM	N
Total Stream Length	**47.00**	**29.21**				
WHISKEY CREEK LINEAGE	**km**	**mi**	**Drainage**	**County**	**State**	**Existing**
Whiskey Creek	2.60	1.62	W. Fork Gila	Catron	NM	Y
Upper Little Creek	3.00	1.86	W. Fork Gila	Catron	NM	Y
Whiskey Creek	4.83	3.00	Gila	Grant	NM	N
Total Stream Length	**10.43**	**6.48**				
GILA MIXED LINEAGES	**km**	**mi**	**Drainage**	**County**	**State**	**Existing**
Lower Little Creek	6.00	3.73	W. Fork Gila	Catron	NM	N
Lower Mogollon Creek	4.00	2.49	Gila	Grant	NM	N
Upper West Fork Gila River	11.90	7.39	W. Fork Gila	Catron	NM	N
	21.90	**13.61**				

Table 5. List of existing and potential restoration streams for the San Francisco River Recovery Unit lineages and San Francisco River-Gila River mixed lineages. Streams with existing populations of Gila trout are indicated by 'Y' in the 'Existing' column, while those that may be considered for restoration of Gila trout are indicated by 'N' in the 'Existing' column. Stream lengths are estimates of the amount of suitable habitat at each location. Sources for stream length estimates were: Gila Trout and Chihuahua Chub Recovery Team, 1999; Gila Trout and Chihuahua Chub Recovery Team, 1997; Johnson, 1999; and Arizona Department of Water Resources, 1994.

SPRUCE CREEK LINEAGE	km	mi	Drainage	County	State	Existing
Spruce Creek	3.70	2.30	San Francisco	Catron	NM	Y
Upper Big Dry Creek	1.90	1.18	San Francisco	Catron	NM	Y
Dude Creek	3.20	1.99	Verde	Gila	AZ	Y
Raspberry Creek	6.00	3.73	Blue	Greenlee	AZ	Y
Lower Big Dry Creek	12.00	7.46	San Francisco	Catron	NM	N
Mineral Creek	2.90	1.80	San Francisco	Catron	NM	N
S. Fork Whitewater Creek	6.80	4.23	San Francisco	Catron	NM	N
Coleman Creek	4.83	3.00	Campbell Blue	Greenlee	AZ	N
KP Creek	17.70	11.00	Blue	Greenlee	AZ	N
Grant Creek	9.65	6.00	Blue	Greenlee	AZ	N
Lanphier Canyon	4.02	2.50	Blue	Greenlee	AZ	N
McKittrick Creek	4.83	3.00	Blue	Greenlee	AZ	N
Castle Creek	2.41	1.50	Campbell Blue	Greenlee	AZ	N
Buckalou Creek	0.80	0.50	Campbell Blue	Greenlee	AZ	N
Total Stream Length	**80.74**	**50.17**				
GILA - SAN FRANCISCO MIX	**km**	**mi**	**Drainage**	**County**	**State**	**Existing**
Grant Creek	6.00	3.73	Aravaipa	Graham	AZ	N
Ash Creek	2.00	1.24	Gila	Graham	AZ	N
Marijilda Creek	2.00	1.24	Gila	Graham	AZ	N
Chitty Creek	8.05	5.00	Eagle	Greenlee	AZ	N
W. Fork Oak Creek Complex	20.92	13.00	Verde	Coconino	AZ	N
West Clear Creek Complex	32.19	20.00	Verde	Navajo	AZ	N
Total Stream Length	**71.16**	**44.22**				

NARRATIVE OUTLINE FOR RECOVERY ACTIONS

1. Establish populations of Gila trout and ensure protection of known, non-hybridized genetic lineages. These lineages are South Diamond, Main Diamond, Whiskey, and Spruce. The Iron Creek and McKenna Creek populations, formerly presumed to be pure Gila trout lineages, were found to be introgressed with rainbow trout. These hybrid populations are no longer considered genetically-pure Gila trout lineages and no longer contribute to recovery of the species.

   1.1 Identify restoration streams and drainage complexes within historical range of Gila trout.

   1.2 Evaluate and select potential restoration streams.

      1.2.1 Determine if a natural barrier to upstream movement of nonnative trout is present or if there is a suitable site for constructing a barrier.

      1.2.2 Evaluate restoration stream in terms of drainage complexity, spatial isolation from parent population, occurrence of nonnative trout, sport fishing use, occurrence of special status species and native fishes, watershed condition, aquatic habitat characteristics, access, and other relevant factors.

      1.2.3 Prepare appropriate level of documentation for National Environmental Policy Act (NEPA) compliance and present restoration stream evaluation and selection in context of NEPA planning process.

      1.2.4 Obtain Clean Water Act section 401 water quality certification and required approvals from local governments.

   1.3 Establish Gila trout in restoration streams.

      1.3.1 Improve habitat conditions, as needed, to provide suitable habitat for Gila trout.

      1.3.2 Construct or improve fish barriers on the restoration stream, if required.

      1.3.3 Remove nonnative trout, if present, from the restoration stream and maintain existing native fish diversity.

      1.3.4 Translocate Gila trout to the restoration streams.

1.4 Develop and maintain hatchery facilities and techniques for propagation of Gila trout for recovery and enhancement efforts.

1.4.1 Develop facilities with capacity to maintain isolated stocks of Gila trout.

1.4.2 Maintain sufficient production capacity to meet recovery program needs.

1.4.2.1 Use surplus production to replace regular stocking of nonnative trout.

1.4.2.2 Identify priority sites for replacement of nonnative trout stocking with stocking of surplus production of Gila trout.

1.4.3 Develop techniques and capacity to maintain all lineages and populations.

1.4.4 Develop brood stock management plan that addresses infusion of wild fish of appropriate lineage to maintain genetic integrity

2. Protect populations of Gila trout.

2.1 Promulgate appropriate regulations to protect populations of Gila trout and improve enforcement of fishing regulations.

2.1.1 Develop a special regulation angling plan.

2.1.2 Develop and implement fishing regulations for Gila trout streams to ensure that mortality from sport fishing does not threaten the viability of any population

2.1.3 Enforce fishing regulations through adequate surveillance of streams by the New Mexico Department of Game and Fish.

2.2 Ensure compliance with section 7 of the Endangered Species Act.

2.3 Monitor populations of Gila trout and their habitat at a frequency adequate to detect effects of land management activities and habitat changes before irreparable population declines have occurred.

2.3.1 Monitor land management activities and habitat conditions and implement adaptive management programs and habitat restoration where needed.

2.3.2 Provide technical assistance and input to land management agencies to ensure restoration of natural watershed function, riparian and upland vegetation structure and composition, and stream habitat characteristics.

2.4 Eliminate nonnative trout from within as much of the historical range of Gila trout as possible.

2.4.1 Replace stocking of nonnative trout with Gila trout. Implement a program of hatchery production and stocking of Gila trout to maintain the existing level of sport fishing supported by nonnative trout production and stocking programs.

2.4.2 Remove nonnative trout from main stem and tributary habitats to allow for repatriation of Gila trout to entire watersheds and drainage basins.

2.4.3 Maintain exclusion of nonnative trout from drainages restored to Gila trout.

2.5 Formalize short-term rescue and refugia strategy for protection of temporarily vulnerable populations.

2.5.1 Identify triggers for implementing strategy.

2.5.2 Describe rescue operations and temporary refugia sites.

3. Continue to investigate aspects of the biology, ecology, life history, habitat, and genetics of the species that are important for conservation of Gila trout.

3.1 Identify information needs based on issues important to conservation of the species.

3.2 Support research programs developed to acquire needed information.

4. Provide information and conduct coordination regarding of recovery actions and issues associated with recovery of Gila trout.

4.1 Develop and distribute informational material regarding recovery of Gila trout.

4.1.1 Develop and distribute news releases for significant recovery actions.

4.1.2 Publish popular articles in magazines, newspapers, and newsletters regarding Gila trout recovery.

4.1.3 Maintain communications with local, state, and federal government agencies, interested groups, and individuals to keep them apprised of recovery actions and progress.

4.2 Invite volunteer participation in recovery actions where such involvement can be accommodated to ensure the safety and adequate supervision of the participants.

4.3 Convene and attend coordination meetings to resolve issues associated with recovery of Gila trout and maintain cooperation.

5. Develop and implement a conservation and management plan following delisting of Gila trout.

   5.1 Prepare a conservation and management plan that specifies long-term management objectives, requirements for monitoring populations of Gila trout, criteria that prompt specific management actions, and identifies participating agencies, roles, and responsibilities.

   5.2 Implement conservation and management plan.

IMPLEMENTATION SCHEDULE

The following implementation schedule that outlines actions and estimated costs for the recovery program. The schedule is a guide for achieving the objective discussed in the Recovery section of the plan and indicates task descriptions, task priorities, task numbers, duration of tasks, responsible agencies, and estimated costs. These actions, when accomplished, should bring about the recovery of Gila trout and protect its habitat. As estimated monetary needs for all parties involved in recovery are identified, this schedule reflects the total estimated financial requirements for recovery of this species.

KEY TO IMPLEMENTATION SCHEDULE

Task Priority

Priority 1 tasks are all of the actions that must be taken to prevent extinction of Gila trout or to prevent the species from declining irreversibly in the foreseeable future. Priority 2 tasks are all actions that must be taken to prevent a significant decline in populations of Gila trout, quality of its habitat, or other significant negative impacts short of extinction. Priority 3 tasks are all other actions necessary to provide for full recovery of Gila trout.

Abbreviations

ES	U.S. Fish and Wildlife Service, New Mexico Ecological Services Field Office
FR	U.S. Fish and Wildlife Service, New Mexico Fishery Resources Office
AZ	Arizona Game and Fish Department
NM	New Mexico Department of Game and Fish
FS	U.S. Forest Service

GILA TROUT RECOVERY PLAN IMPLEMENTATION SCHEDULE

RECOVERY TASK	TASK NO.	TASK PRIORITY	DURATION, YEARS	RESPONSIBLE AGENCY		ANNUAL FISCAL-YEAR COST ESTIMATE, IN THOUSANDS OF DOLLARS									
				FWS	OTHER	1	2	3	4	5	6	7	8	9	10
Identify restoration streams in drainage complexes	1.1	1	5	FR, ES	NM, AZ, FS	5	5	5	5	5					
Evaluate and select streams, NEPA compliance	1.2	1	5	FR, ES	NM, AZ, FS	25	25	25	25	25					
Establish Gila trout in restoration streams	1.3	1	8	FR, ES	NM, AZ, FS	20	20	20	20	20	20	20	20		
Develop and maintain hatchery facilities and techniques	1.4	1	continuous	FR	NM	100	100	100	100	100	50	50	50	50	50
Monitor populations and habitat, provide technical assistance	2.3	2	continuous	FR, ES	NM, AZ	30	30	30	30	30	30	30	30	30	30
Promulgate and enforce fishing regulations	2.1	3	continuous		NM, AZ										
Ensure compliance with section 7 of the Endangered Species Act	2.2	3	continuous	ES											
Eliminate nonnative trout from as much of historical range as possible	2.4	2	10	FR	NM, AZ, FS	20	20	20	20	20	20	20	20	20	20

RECOVERY TASK	TASK NO.	TASK PRIORITY	DURATION, YEARS	RESPONSIBLE AGENCY		ANNUAL FISCAL-YEAR COST ESTIMATE, IN THOUSANDS OF DOLLARS									
				FWS	OTHER	1	2	3	4	5	6	7	8	9	10
Rescue and refugia strategy	2.5	1	5	FR, ES	NM, AZ, FS	2	2	2	2	2					
Identify Information needs based on conservation issues	3.1	2	3	FR, ES	NM, AZ, FS										
Support research programs to acquire needed information	3.2	2	continuous	FR, ES	NM, AZ, FS										
Develop and distribute informational material regarding recovery	4.1	3	10	FR, ES	NM, AZ	5	5	5	5	5	5	5	5	5	5
Involve public in volunteer projects associated with recovery	4.2	3	10	FR, ES	NM, AZ, FS										
Convene and attend coordination meetings	4.3	3	10	FR, ES	NM, AZ, FS										
Total estimated cost per fiscal year, in thousands of dollars						207	207	207	207	207	125	125	125	105	105

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APPENDIX A
PUBLIC AND PEER REVIEW

GENERAL PUBLIC REVIEW

List of agencies requested to provide comments

List of persons requested to provide comments

Commentor

PEER REVIEW

Summarize opinions of all independent peer reviewers asked to respond on an issue

APPENDIX B
INFORMATION STANDARDS

INFORMATION STANDARDS

Information used in the development of this recovery plan included published literature in peer-reviewed journals, articles in the popular literature, unpublished reports from the files of participating agencies, and personal communications with individuals having knowledge on specific issues. All information used is referenced in the *Literature Cited* section of the recovery plan. Personal communications are referenced by individual and affiliation.